FGV CERI

Centro de Estudos em Regulação e Infraestrutura

THE REGULATION OF PUBLIC UTILITIES OF THE FUTURE IN LATIN AMERICA AND CARIBBEAN:

WATER RESOURCE REGULATION IN BRAZIL

30/04/2019

The Regulation of Public Utilities of the Future in Latin America and Caribbean:

Water Resource Regulation in Brazil

Abstract

While 12% of the world's freshwater is located in Brazil, it is unevenly distributed across the country. As a result, water scarcity is a real and present challenge in many areas across Brazil. Scarcity, in turn, creates conflicts among water multiple users. These conflicts are expected to increase due to climate change and the consequent increase in water shortage.

Existing mechanisms for water resource management does not seem sufficient for addressing water scarcity as they do not provide for the reallocation of water. The objective of this paper is, therefore, to examine the desirability and feasibility of creating water markets as a mechanism to promote the efficient reallocation of water.

We conduct a first-principles analysis to show that water markets may dominate other instruments, including water pricing (i.e., a price above and beyond the cost of storing and transporting water to reflect water scarcity). There are two key reasons for favoring water markets over water pricing. First, calculating the correct water pricing is not a trivial exercise. In contrast, a well-designed water market will lead to price discovery and efficient outcomes. The second reason is of a political economy nature. By assigning tradable water rights, users can benefit financially from selling water to a higher value user, whereas a water price is essentially a tax that may not send the correct signal to users.

To assess the feasibility of water markets, we conduct a readiness assessment to identify the main barriers to the creation of water markets in Brazil. Policy recommendations are then provided to overcome the barriers identified in our analysis. For illustration purposes, we simulate the gains from a water market in the São Marcos River Basin. In this river basin agriculture and hydroelectricity generation activities compete for the existing water resources. In a scenario of water scarcity, we suppose that the regulator restricts the use of water that generates an excess demand of 30%. If a proportional rationing system is applied, the total loss of welfare would be 30%. However, if a market for water exists and works competitively, we estimate that the total loss of welfare would only be 2.5%.

1. Introduction

Brazil is known for its abundance of water - about 12% of the world's freshwater is located in Brazilian territory. However, water resources are unevenly distributed due to the country's geographic heterogeneity. There are places where water demand exceeds water supply, which consequently creates conflicts among its multiple users. Conflicts over water use tend to be aggravated as demand increases and climate change intensifies, making cases of scarcity more frequent.

In the national context, water allocation among its multiple uses (e.g., irrigation, urban water supply, industries, hydropower generation) is under the responsibly of both federal and state management bodies. Water allocation follows the doctrine "first come, first served". This doctrine gives the right to use water to the user who requests it first. In cases of scarcity, there is no legally established mechanism for water reallocation among multiple users. In practice, reallocation is negotiated on a case-by-case basis, regardless if it leads to economic efficiency or not (maximization of social welfare). From an economic point of view, the absence of reallocation mechanisms limits the efficiency of water use.

Depending on water availability, the overuse of water by an individual located upstream in a river basin imposes externalities over users located downstream by making water unavailable to them. The overuse of water can also lead to a situation usually called a tragedy of the commons, i.e., the scarcity caused by the indiscriminate use of water resources. Both externality and the tragedy of the commons are known as market failures. These failures prevent the achievement of efficient allocation. For these reasons, it is necessary to think about mechanisms typically used to manage scarce resources that are capable of remedying market failures and achieving feasible and efficient allocations.

A common trend over the years and across the developed world is to introduce market mechanisms to improve the allocation of water across users and to provide a price signal for its scarcity value. As the creation of a water market is an example of this kind of mechanism, this paper analyzes the feasibility of implementing this solution to promote efficient reallocation. For illustration purposes, the particular case of the São Marcos River Basin is presented. As occurs extensively in other basins, agriculture and hydroelectricity generation activities compete for the existing resources in the São

Marcos River Basin. This case study aims to simulate market gains in a basin where conflict over water use exists.

This study is organized as follows. After this introduction, section 2 addresses the economic aspects of water resource management and the instruments capable of promoting efficient allocation. Section 3 describes the Brazilian water resource management framework and analyzes its limitations. Seeking inspiration from a successful water market creation, section 4 presents the case of Australia's Murray Darling River Basin. Section 5 presents a readiness assessment, aiming to identify the main barriers to the creation of water markets in Brazil. Finally, section 6 draws policy recommendations to deal with the identified barriers. The São Marcos River Basin case study is discussed in section 7. We describe the case and assess the potential gains from the implementation of a water market in that basin.

2. Managing Scarce Resource

In this section, we discuss the need for an economic mechanism that leads to an optimal allocation of water in the presence of scarcity. We then analyze the current framework and investigate the reason why the mechanism in place pose problems to an efficient allocation. Finally, we expose the alternatives to manage water resources efficiently. To preserve clarity, we let the technical notes with the formal derivations in the Appendix.

2.1 The Need for Management in Common Properties

The problem of exploring resources in common property is well known in the economic literature. Since all users take only their private interest under consideration when deciding how much to explore a shared-resource, they tend to overexploit it. This problem is known as the "tragedy of the commons".

In our case, the shared-resource is the water available in a water body. If all users were able to abstract water with no proper management scheme, overuse and depletion might occur.

To illustrate the problem, suppose that N irrigators want to abstract water from a water body. Let the total production of an irrigator that abstracts an amount of water q_i be equal to $f_i(q_i)$ and the price of his/her good sold be p_i. If the irrigator i is to decide how much

water to abstract from the water body, he/she will decide to abstract the quantity q_i* that solves $p_i f_i'(q_i*)=c_i$. In other words, he/she will decide to abstract the quantity that equates his/her value of marginal productivity to his/her private marginal cost.

If the available amount of water in the water body, Q, is greater than the sum of the individual optimal quantities, there is no problem of scarcity and no mechanism to achieve efficiency is needed.

On the other hand, if the available quantity is smaller than the sum of the optimal individual quantities, we say that the individual decisions will cause an externality problem and at least one of the irrigators will end up with an abstraction smaller than the quantity he/she decided to abstract.

This problem occurs because each irrigator decides how much water to abstract based on his/her private costs only. The quantity of water available to others is not considered when the individual decision is made.

We will see that, depending on the mechanism of water allocation, this externality may pose a problem of misallocation, that is, less efficient producers may end up with no water to abstract from.

2.2 The Current Mechanism in Brazil: A First Come, First Served Approach

The actual Brazilian water resource management works in a "first come, first served" approach[1]. The main economic problem of this approach is the lack of a redistribution scheme (mechanisms for reallocation). Since the water availability is not always sufficient to fully meet its demand, an inefficient allocation may arise from this distribution process.

To illustrate the problem, suppose that actual water demand exceeds its availability. Since there is no link between efficiency and the water allocation process, there is nothing to

[1] See more in subsection 3.4.

prevent the less efficient producers from claiming the right to use water letting the most efficient producers without access to it.

If the most efficient producers (i.e., the ones with higher private marginal value in the use of water) cannot buy/trade water rights from the less efficient, total welfare will not be maximized.

2.3 Alternative Approaches for Water Allocation

Different allocation mechanisms may or may not lead to an efficient allocation of water. We will focus our discussion in the two most common approaches in the economic literature: competitive market and price setting mechanisms.

In a competitive market, the efficient allocation is achieved by trading. The existence of a market for water rights allows the most efficient users to buy the rights from the less efficient ones. The competitive equilibrium is achieved with a price that equates demand to supply. Since all participants in the market face the same price, the trading scheme needs little information to work properly.

We showed that when deciding how much water to extract, the irrigator chooses the quantity that equates his/her value of marginal productivity to his/her marginal cost. Since, in the presence of a water market, the marginal cost is just the common water price faced by the producers, the value of the marginal productivity of water must be equal to the water price.

Since this must be true for all profit-maximizing producers, the value of marginal productivity must be the same for all of them. The condition of equal value of marginal productivity between firms is a condition of Pareto optimality. If marginal valuation differs, then there is an opportunity of reallocation that can increase the welfare for all.

The Pareto optimality of the competitive market is known as the First Social Welfare Theorem. One should recall that the First Social Welfare Theorem is silent about equity concerns. However, the matter of equity can be addressed through the distribution of water rights. The possibility of water trading will naturally transfer the rights from the less productive to the more productive ones. As a result, the less productive will receive the value from sales of their water rights.

An alternative approach to promote the efficient allocation of water would be a price system. Price setting occurs when the government determines the price that must be paid for the use of water. Usually, it occurs by the imposition of a tax per amount of water abstracted. There are many ways to set a price with economic meaning. One good price candidate is the competitive equilibrium price. If the government set the price of water equal to the competitive price, efficiency can be achieved.

The government may also want to set a price to maximize the value of permits sold. If this is the objective, then the price set must be a monopoly price which is higher than the competitive price. In this case, the government maximizes tax revenue, but it sacrifices social welfare in turn. With a higher price, not all the available water is used, and the total welfare is reduced.

There is one possible way that, at least theoretically, the government could maximize tax revenue without sacrificing social welfare. It is the case where the government could perfectly discriminate the use of water.

Price discrimination involves selling different units of the same good at different prices, either to the same or different consumers. For price discrimination to be feasible, the firm, in our case, the government, must be able to sort consumers and prevent resale. There are three types of price discrimination.

First-degree price discrimination (or perfect price discrimination) involves charging the maximum willingness to pay for each unit of the good sold.

Second-degree price discrimination (or non-linear pricing) involves charging different prices for different amounts of the good purchased.

Third-degree price discrimination involves charging different prices for different purchasers, but each consumer faces a constant price per unit sold.

Theoretically, efficiency can be achieved with first-degree price discrimination. The difference from this case to the competitive market is that with perfect price discrimination all the surplus is captured by the seller (in our case, the government).

Unfortunately, the practical implementation of this mechanism relies on the assumption that the government would know the willingness-to-pay (value of private marginal productivity) for each producer for each unit of water sold. Since this precise information is very difficult to obtain, perfect price discrimination is not feasible.

In the second-degree price discrimination, the government problem is to differentiate the large buyer that has higher willingness-to-pay from the smaller buyer, with lower willingness-to-pay for the same amount of water.

The main practical problem is that since the government does not know which buyer has higher willingness-to-pay for water, the price for the small buyer must be greater than it would be in an observable willingness-to-pay scenario. This price premium is necessary for the higher willingness-to-pay producer to consume the amount of water intended for him. The welfare loss caused by this price premium is known in the economic literature as an information rent.

Finally, in the third-degree price discrimination, if the government were to maximize its profits (total value of permits sold), it should charge a higher price for the consumers with a lower elasticity of demand.

There are two reasons why the government should not pursue this. First, to maximize profits, it must use its monopoly power and charge a price for the use of water potentially higher than the social optimum. Second, the users with less elasticity of demand are usually the ones for which water is essential, which may pose an equity problem. As we present in section 3, the current water charge structure in the São Francisco River Basin resembles a third-degree price discrimination description.

Price setting mechanisms, in general, rely on the capacity of the government to obtain precise information as a good estimation of the demand curve. It makes the government susceptible to the pressure of economic and political agents that may have private interests that differs from social interest. After the price is set, there is no guarantee that changes in demand will make the price efficient even if before the changes it were.

In that regard, a water market seems to be a better solution to manage scarce water resources since it requires less information to work properly. To add to that, the allocative efficiency may be reached even with changes in demand. There are already several cases

of successful water market implementations, such as Murray Darling Basin in Australia, Western United States and Limarí Valley in Chile (Grafton *et al.*, 2010a).

3. Brazilian Water Resource Management

This section presents the context of Brazil's water resource management. It analyzes the legal, regulatory and policy framework, aiming to identify the key challenges.

3.1 Overall availability and use of water

Around 12% of the world's freshwater resources are located on Brazilian territory. However, water is highly unequally distributed across the country. For example, the average annual water flow in the Amazon Hydrographic Region reaches 73,700 m³/s, while in the Oriental Northeast Atlantic Hydrographic Region amounts to 92 m³/s (ANA, 2015)[2].

Regarding water quality, domestic wastewater discharge is the main problem. Currently, 40% of the population still lack sewage collection, and just 45% of sewage is treated (SNIS, 2016). As a result, about 4.5% of the rivers have a high concentration of organic matter. It restricts the uses these waters can have (ANA, 2017a).

Total water abstraction amounts to 2,083 m³/s in 2017 (ANA, 2017b). Agriculture is the major water use, representing around 50% of water demand. Urban water supply is the second, demanding 23% of total abstraction. Water use efficiency is also a concern. Losses in irrigation can reach 70% (FGV EESP, 2016), and currently 38% of the drinking water produced in the country does not reach consumers (SNIS, 2016).

Hydropower represents 12% of Brazil's energy matrix (EPE, 2018). There are 644 hydropower plants in the country. Even though it is a non-consumptive use, it impacts river flow conditions. It can also affect water availability due to the high evaporation rates in reservoirs with large superficial areas. According to ANA (2019), the mean net

---

[2] Brazil is divided into 12 Hydrographic Regions: Amazon, Tocantins-Araguaia, Northeast Atlantic – west region, Parnaíba, Northeast Atlantic – east region, São Francisco, East Atlantic, Southeast Atlantic, Paraná, Paraguai, Uruguai and South Atlantic. Each hydrographic region water availability can be seen in ANA (2015).

evaporation in reservoirs reached 669.1 m^3/s in 2017. It corresponded to the second most consumed water use (water was most used by irrigators).

3.2 Legal Framework

According to the Federal Constitution all waterways that cross states within the country, that serve as boundaries with other countries, or that extend into foreign territory fall under the responsibility of the federal government. States are responsible for surface or subterranean waters, except for those resulting from work carried out by the federal government. Thus, the water resource management framework operates both at national and state levels.

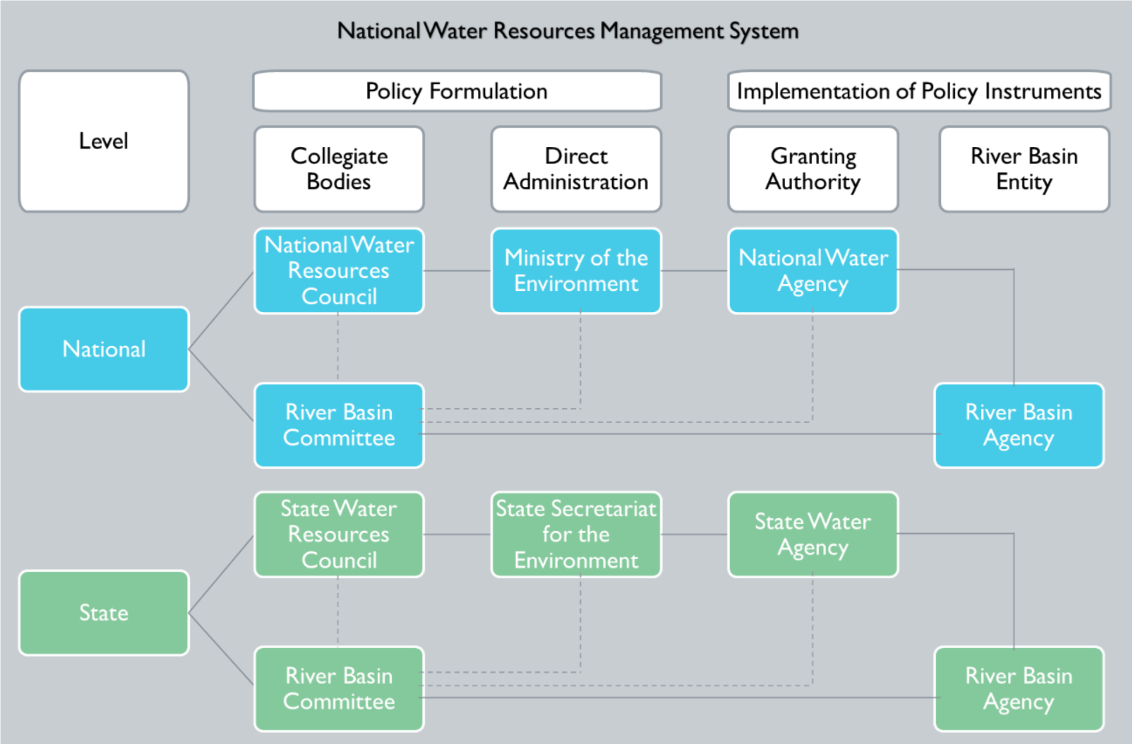
The double jurisdiction adds complexity to the water resources management system. As the river basin[3] boundaries do not always coincide with state boundaries, there is more than one body responsible for water resource management. Thus, the higher the number of bodies in charge of different sections of a river basin, the higher the need for coordination between them to properly manage the water resource.

3.3 Institutional Framework

The 1997 Water Act (Federal Law number 9433) set the institutional framework for water resource management in Brazil. Figure 1 describes the National Water Resources Management System. The roles of each institution are presented below.

[3] A river basin is the portion of land drained by a river and its tributaries.

Figure 1 - The National Water Resource Management System



Source: FGV CERI.

Ministry of the Environment / State Secretariats for the Environment

The Ministry of the Environment formulates water policy at the federal level. State secretariats undertake this role at the state level.

National / State Water Resources Councils

The National and State Water Resource Councils are normative and deliberative bodies. Their functions include the coordination of water resource plans with other sector plans (such as sanitation, agriculture, and industry), the approval of the creation of river basin committees and the definition of general criteria for granting water permits and implementing water charges.

Some State Water Resource Councils were created before the establishment of the 1997 Water Act especially in the Northeast, due to the water scarcity, and in the Southeast, due to pollution problems. Some examples are the São Paulo and Ceará State Water Resource Council created in 1987 and 1992, respectively. According to OECD (2015), the maturity of the councils varies.

River Basin Committees

River basin committees (both at national and state levels) are deliberative and consultative bodies for water resource management at the river basin's scale. They are responsible for arbitrating disputes between the different water resource users within the river basin's limits and for approving river basin plans. These committees also establish the water charge[4] structure and propose the amounts to be collected. Representatives from the federal, state and city governments, as well as from the water users and civil society compose these committees. The composition and number of representatives vary across river basin committees.

There are some issues regarding the committees' composition. First, there are regularly new members on committees due to the political cycle. Thus, frequent changes and the consequent lack of institutional memory are challenging (OECD, 2015). Second, there is a governance problem. There is no guarantee that a member of the committee will have the technical expertise required to perform committees' roles nor that their decisions will be taken regardless of their interests. Therefore, some relevant decisions can become political as a result of negotiation amongst water users and other river basin committees' members. That is the case of the water charge setting. We discuss this further below in section 3.4.

River Basin Agencies

River basin agencies (both at national and state levels) may be established to act as executive secretariats for the committees. If these agencies are not established, their role is performed by state water agencies.

National / State Water Agency

The National Water Agency (NWA) regulates water resources under federal responsibility, whereas state water agencies regulate state rivers.

---

[4] Water charge is an instrument for water resource management in Brazil. It refers to the value paid by the users of raw water. The water charge is collected by the water resource regulatory agency. It differs from water tariff paid by final consumers to water utilities.

Regarding the role of the NWA, a provisional measure[5] (PM) that adds a new responsibility to this body is currently under discussion in Congress. It states that the NWA will also be responsible for establishing national benchmarks for sanitation services[6] regulation. This PM provides an integration/homogeneity that may lead to more consistent regulation nationwide. Moreover, the PM may be an initiative to manage both water resources and the sanitation sectors in an integrated way. It is important as the human water supply is the top priority among multiple users.

3.4 Policy Framework

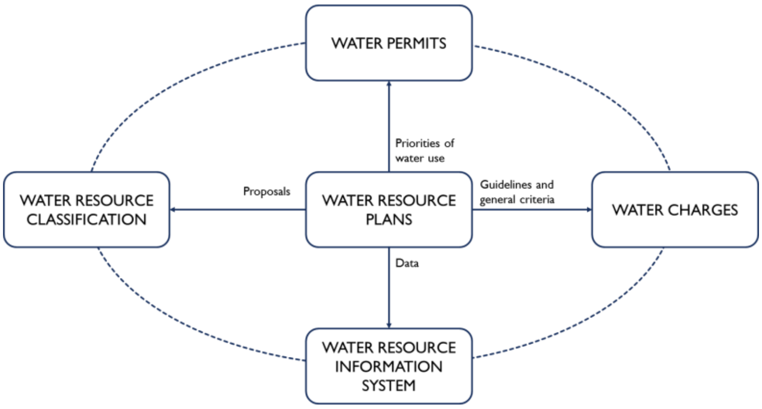
The 1997 Water Act established the National Water Resource Policy, which is based on the following key principles:

- Water resource management should promote multiple uses of water;
- The river basin is the territorial unit to implement the Water Resource Policy; and
- In situations of water scarcity, the top priority among multiple users is human needs and animal consumption.

The 1997 Water Act introduced six water resource management instruments: (i) water resource plans; (ii) water permits; (iii) water charges; (iv) water resource classification into classes according to the main water use; (v) cities compensation; and (vi) water resource information system. Figure 2 depicts how these instruments relate to one another. We analyze just the former three instruments since they affect the water allocation process the most.

[5] Provisional Measure number 868/2018.
[6] According to Brazilian Sanitation Act, sanitation services include: (i) water supply; (ii) wastewater collection and treatment; (iii) urban solid waste management; and (iv) stormwater management.

Figure 2 - National Water Resource Policy's Instruments



Source: ANA, 2017a

Water Resource Plans

The water resource plan integrates all other instruments (Figure 2). Water resource plans are developed for river basin, state and federal scale. Despite its importance, the water resource plan has not been used as an efficient instrument for water resource management. There are three main reasons. First, they are often ill-crafted as they incorporate projects that are not feasible (either technically or economically or both). Second, even well-crafted plans are rarely implemented due to limited funding, technical capacity, monitoring and enforcement (OCED, 2015). Finally, these plans fail to drive water allocation decisions as they usually do not define the criteria to prioritize allocations.

Water Permits

Water permits provide the user the right to use water[7]. It ensures water availability and reliable access for permit holders. Permits are issued through an administrative act by the NWA and by the state water agencies at federal and state levels, respectively (see Box 1). It specifies the amount of water each permit holder can utilize for different purposes – such as abstraction, consumption and discharge – and its conditions.

---

[7] Water rights differs from property rights in economic sense. As per economics, property rights are the theoretical and legal ownership of a good by individuals and the ability to determine how such property is used, so trades are allowed. In the case of water in Brazil, water rights are not tradable. They guarantee the user only the right of use water and they do not imply the partial appropriation of water. As already mentioned, the federal government and the states issue water rights, so we can understand that water is a "property" of the federal government and the states.

Box 1: Permit granting process at the federal level

The permit granting process at the federal level[8] begins with a request sent by the permit applicant to the Federal System of Regulation of Use (REGLA)[9]. Based on the information given by the applicant himself/herself, the NWA's team analyzes whether or not the water flow requested is suitable for its use. For example, if the user requires water for irrigation purposes, the agency estimates its water consumption based on information such as the type of crop, irrigated area, and irrigation technique. To avoid overuse of water, the NWA tries to match this estimated consumption with the requested flow.

Once approved, the requested flow is then checked against the river basin's water availability, which is measured in terms of a reference flow. The decision-making process on whether to grant a permit is based on a water balance system that is updated with every new user added. Figure 3 presents the schematic permit process analysis conducted by the NWA.

Figure 3 - Permit Process Analysis

Source: FGV CERI

As water resources in a basin belong either to the state or to the federal government, the interaction between NWA and state agencies is essential during the permit granting process. However, this integration has not been effective until November 2017, when REGLA system was implemented. By that date, besides federal information, data from the states of Maranhão, Pará, Piauí, Rio de Janeiro, Rio Grande do Norte, and Tocantins were included in the system.

The allocation mechanism through water permit follows the doctrine "first-come, first served". This doctrine does not take into account the economic benefit that each user generates by using water. It does not guarantee that water will be allocated to the most

[8] Information based on an interview with a specialist from the National Water Agency.
[9] This system is available at:< http://www.snirh.gov.br/cnarh/index.jsf.>

efficient users. Allocation efficiency becomes limited by the current regulatory framework that does not allow permits to be traded.

Water Charges

Water charge is a value that permit holders pay to use water. According to the 1997 Water Act, water charge must: (i) recognize water as an economic good and send users a signal of its value; (ii) encourage the rationalization of water use; and (iii) be sufficient to finance programs and interventions defined by the river basin's plans.

The amount charged is calculated by multiplying the water abstraction, consumption and/or discharge (metered and/or permitted) by the Unitary Public Prices (UPP) (see Box 2). The UPP is the price charged per m^3 of water, and it is proposed by the river basin committees. There are two issues concerning the setting of UPP. First, the committees usually carry out only an assessment based on the impact of the charge on water users' costs. Thus, the amount charged does not reflect opportunity costs nor the externalities associated with the use of water. Second, as water users are also members of these committees, the UPP decision is not entirely independent. As a consequence, this decision is predominately political. Water charge as it is currently applied fails to meet the first two goals defined by the legal framework.

Box 2: São Francisco River Basin's water charge structure

Water abstraction and consumption are charged differently.

Water abstraction

The amount charged for water abstraction in the São Francisco River Basin is calculated as follow:

$$Charge_{abstraction} = Q_{permit} \text{ x UPP x } K_s^*$$

K_s^* comprises coefficients that are specific for each user, as it takes into account the user's sector, his location (if it is a rural or urban area) and the classification of the river from which the user is abstracting water. In the specific case of the agriculture sector, this coefficient varies according to irrigation techniques, and water and soil management.

In the cases where water abstraction is metered, Q_{permit} is replaced by a weighting between metered water abstraction and permitted flow.

Water consumption

The following formula calculates the amount charged for water consumption:

$$Charge_{consumption} = Q_{consumption} \text{ x UPP x } K_s{}^*$$

Due to the difficulty of estimating irrigation water consumption, the amount charged is calculated by multiplying the permitted flow by a coefficient that varies according to the irrigation method.

For more details, see CBHSF (2017)

Although established by different committees, water charges in Brazil are overall similar in terms of their values and generally lower than the necessary (see Box 3). The low value of the charges does not incentivize users to reduce their consumption. To add to this, a NWA study demonstrates that until 2016 the value collected at the federal level were able to cover about 10-15% of the financing needed to implement actions foreseen in water resources plans (e.g., studies, projects or construction works) (ANA, 2016). As a consequence, additional financial resources are needed to fill financing gaps. It demonstrates that this instrument also fails to reach target 3.

Box 3: PPU in Federal River Basin Committees

Table 1 presents the UPP charged for water abstraction and consumption by each of the federal committees that have already implemented water charging.

Table 1 - UPP's charged for water abstraction and consumption

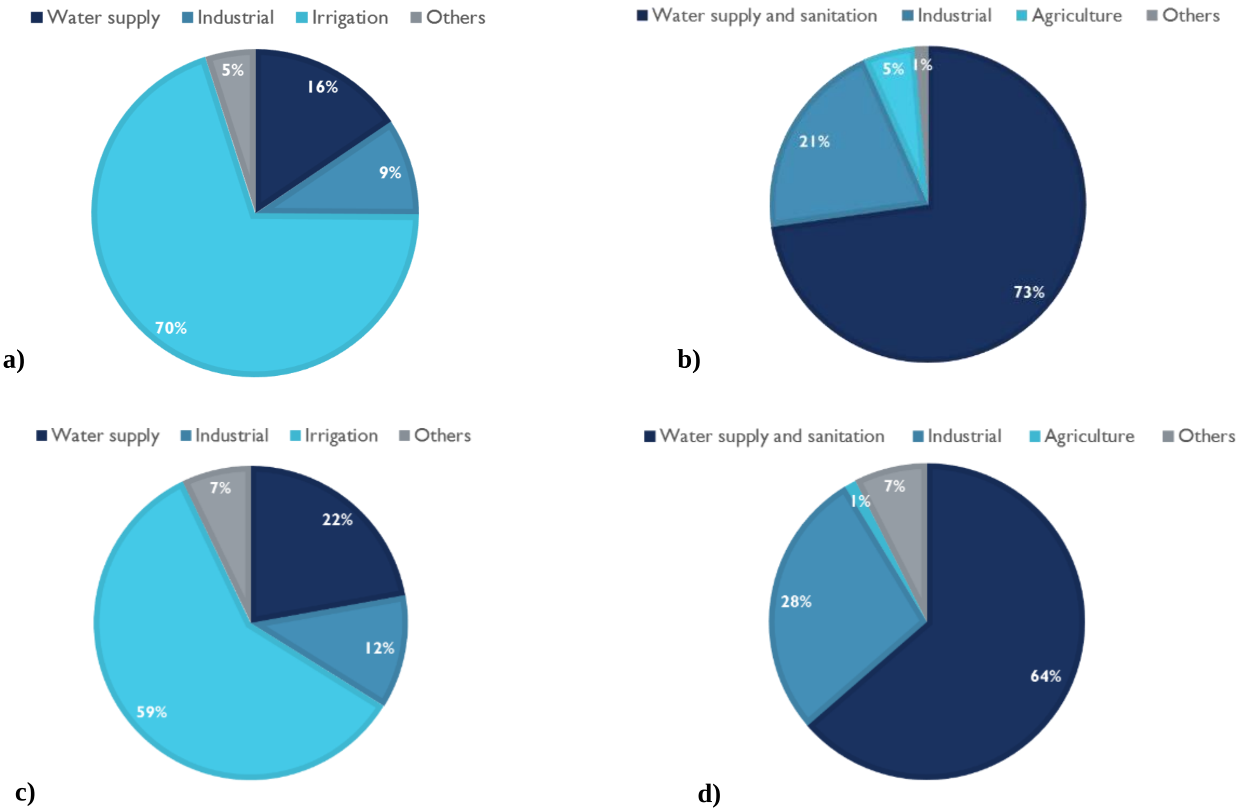
	Paraíba do Sul	São Francisco	Doce	PCJ	Paranaíba	Verde Grande
Abstraction (R$/m³)	0.01	0.012	0.0308	0.01	0.015	0.0101
Consumption (R$/m³)	0.02	0.024	-	0.02	-	0.0202

Source: CBH-Verde Grande (2015); CBH-Paranaíba (2016a); ANA (2010a); CBHSF(2017) and CBH-DOCE(2018)

The perverse subsidy provided for irrigators must also be highlighted in this analysis (Box 3). This subsidy discourages the rational use of water in the agriculture sector. Figure 4

shows that even though irrigators are the main users of water, they bear only 5% of the amount collected by state agencies and 1% by the NWA. Under the current regulatory regime, farmers pay only 2-5% of what other users pay on a volumetric basis (OECD, 2017). This has to do with the application of a reduction coefficient introduced at the price charged for the agricultural sector.

Figure 4 – Comparison between water permits and water charge. a) and b) shows water permits issued by the NWA and the amount collected through water charge at the federal level, respectively; c) and d) how water permits issued by state agencies and the amount collected through water charge at the state level, respectively



Source: ANA(2017b)

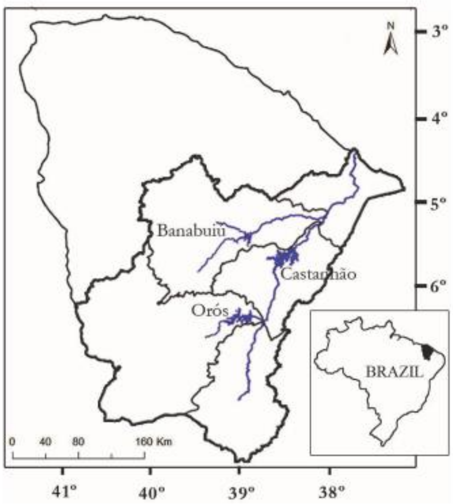
This coefficient is designed aiming not to impact the competitiveness of agricultural products. However, there is no solid evidence that the amount charged would truly impact irrigators' costs. The low contribution of the agriculture sector may be due to its influence on the decision-making process rather than to the assessment of the impact on water users. Given our discussion thus far, we conclude that water charge in Brazil does not drive decisions on how much water each user consumes. Thus, we cannot refer to it as price regulation. Water charge as currently implemented in Brazil is a simple mechanism to generate revenues rather than a water policy tool.

After discussing three of the instruments adopted in the water resource management in Brazil, we notice that they seem to have been designed based on an abundance water framework. The permit granting process does not take into account any efficiency criteria. The way it was designed does not envisage the possibility of not having enough water to meet all demand. As the water resource policy does not provide for any reallocation mechanism, the allocative efficiency remains limited. We conclude that the current instruments are not sufficient to cope with the increasing conflicts over water use and water stress situations (see Box 4).

Box 4: Agricultural Conflicts in the State of Ceará

The Jaguaribe and Banabuiú Valleys are located in the State of Ceará, Brazil´s semi-arid region. The Orós, Banabuiú and Castanhão Reservoirs are responsible for water supply in these valleys (Figure 5). This region experienced a severe drought in the early 2000s.

Figure 5- Location of Orós, Banabuiú and Castanhão Reservoirs



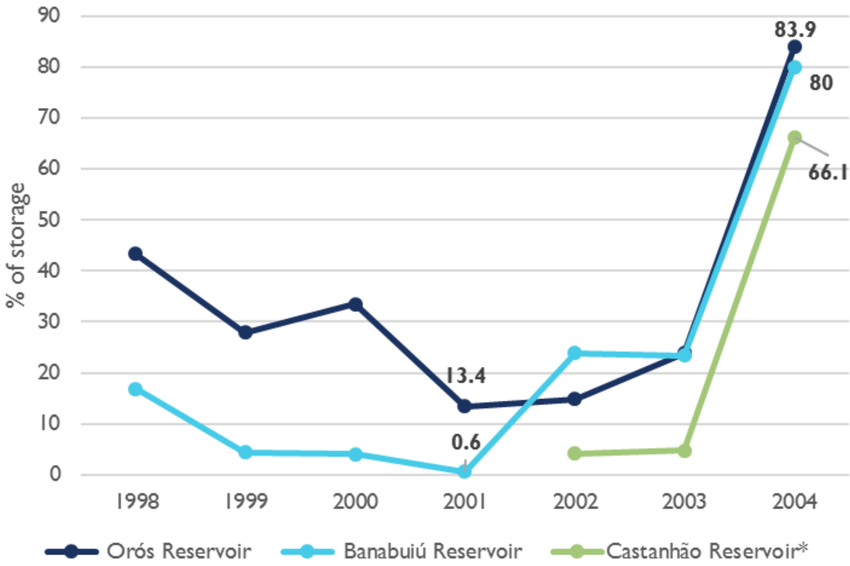
Source: FERNANDES *et al.*, 2017

At that time, the main water use in the Jaguaribe River Basin was irrigation. It represented 83% of the total abstraction. The Jaguaribe and Banabuiú Valleys had 26.000 hectares of irrigated land, mostly irrigated by the flooding method - a low-efficiency method. Rice production occupied approximately 45% of this area (DA SILVA *et al.*, 2006).

When the rainy season (February to June) ended in 2001, the volume stored in the Orós and Banabuiú Reservoirs was insufficient to meet the irrigation demand (Figure 6). It was made necessary to adopt a rationing plan involving the Water Resources Company

(COGERH), the State Secretariat for Agriculture, Rural Development and Development (SEAGRI), the Secretariat of Water Resources of the State of Ceará (SRH) and the NWA.

Figure 6 – Orós, Banabuiú and Castanhão's storage



** Castanhão Reservoir started operation in 2002.*

Source: FGV CERI based on Silva et al. (2006)

In the Banabuiú Valley, it was not necessary to adopt strategies for water reallocation, since the water availability had been sufficient to meet only human needs. To preserve water availability for human consumption (top priority use), all other users were rationed.

In the Jaguaribe River Valley, another approach was adopted since there was water available to meet the irrigation demand partially. It was introduced a program that prioritized fruticulture instead of rice production, as the former was worth more than the latter considering the economic and social aspects (e.g., employment)[10]. Under this program, rice farmers were compensated for foregoing to plant. This compensation was either non-pecuniary[11] or financial[12]. Fruit producers partially funded this program. They agreed to contribute since the amount paid would be well below the cost of rationing (KELMAN, 2009). Water availability returned to normal conditions by the following year.

[10] The economic value of each cubic meter of water used in fruit production is higher than that of rice (KELMAN, 2009).

[11] Non-pecuniary compensation included the provision of training and the identification of regions suitable for planting less water-intensive crops.

[12] Financial compensation included the provision of credits to farmers to start planting in the new identified region.

The program implemented in Ceará brought a new approach to water resource management by using economic incentives. Although it is not widespread in the country, perhaps due to lack of a supporting legal and regulatory framework, this case illustrates that even in the absence of formal markets the use of an economic mechanism to reallocate water can lead to positive results.

Based on our discussion about Brazilian water resource management, we conclude that :

- The Water Resource Management Policy's instruments were designed not considering the possibility of water scarcity. Although the country is known for its water abundance, there are problems regarding the spatial distribution of water. Water users are concentrated away from the main sources of water.
- The double jurisdiction requires an adequate integration between federal and state information. However, there is a lack of coordination between state and federal management bodies, which endangers the water resource management as a whole;
- Water resource plans do not define priority criteria for water use. Hence they fail to guide the permit granting process. Thus, the allocative instrument (water permit) is based solely on "first come, first served" doctrine;
- There is no economic mechanism to allocate water among multiple uses. It compromises the efficiency of water allocation;
- Low institutional capacity of river basin committees weakens water resource management instruments. The committees gather responsibilities that depend on technical skills. However, their decisions, such as the definition of water charge, are often based on political influence. This compromises the effectiveness of the instrument;
- Water charge as currently implemented is an instrument adopted to generate revenues rather than a water policy tool. It does not send right price signals to users, undermining efficiency in water use;
- Water scarcity and conflicts over water use have become increasingly frequent even in well-developed regions. The instruments currently adopted in the Brazilian's water resource management does not seem to be sufficient to cope

with these situations. There are no reallocation mechanisms foreseen in the Water Resource Management Policy.

In the next sections, we focus on the last topic. We analyze the feasibility of creating water markets in Brazil to promote efficient reallocation. We highlight that we do not believe that this mechanism fits all Brazilian river basins reality. We aim to analyze in what way allowing the negotiation between water users could help the management of water scarcity situations. For a sense of this, the experience of Australia's Murray-Darling Basin is broached to seek inspiration that may be relevant to the introduction of water markets in Brazil.

4. The Experience of Australia's Murray-Darling Basin

The Murray–Darling Basin (MDB) is located in southeastern Australia. It is the largest and most complex river system in Australia. It drains almost 15% of Australia's territory, including four Australian states and one territory: Queensland, New South Wales, South Australia, Victoria and the Australian Capital Territory (Figure 7). Also, the MDB has an important economic role. More than 2.6 million Australians live in the Basin area. Agriculture in the Basin produces AU$24 billion every year. There are approximately 9,200 irrigated agriculture businesses and about 2 million hectares of irrigated agricultural land in the basin. Tourism is also a relevant economic activity which adds AU$8 billion dollars annually to the basin (MDBA, 2018).

Figure 7- Murray-Darling Basin

Source: MDBA, 2018

As the Murray-Darling Basin is located in a semi-arid region, many supply strategies, such as water markets, have been implemented and developed to mitigate water scarcity (GRAFTON *et al.*, 2012). To make water reallocation strategies possible, several reforms were necessary. In the late 1880s, Australia's states had transformed riparian water rights into statutory water rights (called water entitlements). By the 1980s the pressure for water rights to be separated from land rights, and for it to be tradable, increased due to an over-allocation of statutory water rights. During this decade water markets were established in the four states of MDB (GRAFTON *et al.*, 2012). One should recall that water resource management is a state responsibility in Australia.

Further reforms in water trading took place in 1994 with the Council of Australian Governments' (CoAG) Water Reform Framework, and again in 2004 with the National Water Initiative (NWI) (GRAFTON *et al.*, 2012). The latter is an intergovernmental agreement between the federal government and the Australian States and Territories to increase water use efficiency. Under the NWI, governments commit to: (i) prepare comprehensive water plans; (ii) achieve sustainable water use in over-allocated or stressed water systems; (iii) introduce registers of water rights and standards for water accounting; (iv) expand trade in water rights; (v) improve pricing for water storage and delivery; and (vi) better manage urban water demands.

The 2007 Water Act established the MDB Authority as an independent expertise-based statutory agency. Among the things the Authority is responsible for are: (i) the integrated plan for the sustainable use of the basin's water resources; (ii) operating the Murray River system and efficiently delivering water to users on behalf of partner governments; (iii) measuring and monitoring the basin's water resources quality and quantity; (iv) advising the Australian and State Governments on water resource matters; and (v) providing water rights information to facilitate water trading across the basin (MDBA, 2018).

The Water Act 2007 also defined three different types of tradeable water rights (entitlements):

1. Water access right, which is any right conferred by or under a law of a state to hold and/or to take water from a water resource. This kind of right includes the following rights:

a. Stock and domestic rights;
b. Riparian rights;
c. Water access entitlement: a perpetual or ongoing entitlement, by or under a law of a state, to exclusive access to a share of the water resources of a water resource plan area; and
d. Water allocation: a specific volume of water allocated to water access entitlements in a given water accounting period.

2. Water delivery right, which is a right to have water delivered by an infrastructure operator; and
3. Irrigation right, which is a right that a person has against an irrigation infrastructure operator to receive water.

Water rights can have different levels of reliability. It is related to the probability of rationing water rights holders. As Grafton *et al.* (2012) explain, water entitlements provide their holders with "a share of a consumptive pool, but the actual quantities of water that holders of entitlements are permitted to divert depend on the seasonal allocation that is assigned each year to the water entitlement". The seasonal allocation defines which entitlements holders have and how much water may be diverted considering water entitlement's level of reliability. The higher the reliability of the water entitlements, the higher the chances the volume of water allowed to be diverted will be equal to the water entitlement.

In Australia, both water entitlement and seasonal allocation can be traded. They are respectively called permanent and temporary trade. Seasonal allocations have generally represented the majority of trades since access to water is more assured with this kind of right. The trade price represents the value of the water access right and is not regulated. However, according to the water trading rules, the seller must notify the authority of the trade price (ACCC, 2016).

According to the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2018), high-reliability water entitlement trades in 2016-2017 were on average AU$ 2,559.00/ML, while medium and low reliability were, respectively, AU$ 2,150.00/ML and AU$ 434.00. However, in the same period, water allocation trades were on average AU$ 77,6/ML. It is important to mention that water market prices also vary with catchment.

The MDB market is mainly composed of irrigators. The main beneficiaries are orchard and vineyard farmers. By volume, over 1,499 GL of water entitlements were traded in

2016-2017, while about 6,000 GL of seasonal allocations were traded over the same period. The total value of turnover in entitlement trade was about AU$901 million[13], and about AU$130 million in terms of seasonal allocations in 2016-2017.

MDB experience shows that the implementation of market mechanisms is also compatible with environmental sustainability issues. The water law reform that allowed water to be decoupled from land along with the maturing period of water resource management was essential to the success of the MDB water market. Moreover, in this case, it is worth highlighting the importance of the integration between federal and states roles. Finally, the connection between the water market and water planning provide more security for water right's holders and environmental outcomes.

5. Readiness Assessment of Brazilian Water Resource Management

The implementation of water markets as an instrument for water resource management requires a prior design of institutional arrangements. The necessary reforms to design and implement successful water markets must follow a certain sequence that will lead to robust and adaptive water governance. According to Young (2014), introducing trade without fixing the flaws in the water allocation regime that is already in place may not be a good starting point. Moreover, Wheeler *et al*. (2017) state that implementing water trading without fully strengthening institutional and administrative capacity may result in high transaction costs[14] and may reinforce the resistance to the introduction of market policies.

The degree of water market regulation must be properly balanced. On one hand, excessive regulation can result in high transaction costs and reduce the benefits of water trading. On the other hand, inadequate regulation can impose unacceptable costs on third parties or the environment (ROSEGRANT AND GAZMURI, 1995).

The feasibility of developing water markets depends on the interactions between the hydrological, infrastructural, legal and political regimes (ROSEGRANT AND GAZMURI, 1995). Regarding hydrological matters, effective market-based reallocation

---

[13] Price data only available for New South Wales, Victoria and South Australia.
[14] Transaction costs include, for example, bureaucratic administrative costs, identification of potential buyers/sellers, obtaining hydrological information related to water availability, and negotiating and recording transactions (FGV-EAESP, 2018).

policies require public information on water availability for consumptive uses and existing rights. Hydrological monitoring, data collection and a registered system that includes all permitted users are desirable. As per infrastructural matters, "water trades require connected (natural or built) infrastructure to facilitate the movement of water from the sellers to the buyer" (Grafton and Peterson, 2007).

Water trading must be foreseen in the legal framework. This also depends on the existence of clear operational rules: how, where and how much water can be either used or traded. Relationships between rights must be well defined so that users understand their rights to water and how to transfer it. It should be clear that if a user wishes to access a higher amount of water than the amount already established in the permit, they should convince another user to use less water.

Moreover, water rights must be enforced by not allowing new rights to interfere with already existing ones without proper compensation. This can be achieved by monitoring and controlling water uses to ensure all users comply with the conditions pre-established in their permits. These rights must also ensure a reliable level of water access. From a market perspective, there should be a secure and predictable delivery.

Finally, political factors such as the different degrees of government willingness to empower people, different perceptions regarding the degree of regulatory interference in managing resources and the political interests of the main stakeholders are important in determining whether, and to what extent, marketable trades will be established (ROSEGRANT AND GAZMURI, 1995).

Considering the mentioned requirements, we evaluate in the national context aiming to identify barriers and opportunities for the introduction of market-based policies in Brazil. The evaluation, based on Wheeler *et al.* (2017) and Matthews (2004), takes into consideration the following components: (i) **water rights regulatory framework**; (ii) **institutional governance**; (iii) **data collection**; (iv) **operational rules**; (v) **market for water-trading** and (iv) **arrangements to deal with externalities**. Table 2 summarizes the questions we aim to answer in each one of these points.

Table 2 – Water market readiness assessment – questions

Water Rights Regulatory Framework

- Are water rights clearly defined?
- Can water rights be decoupled from land property?

Institutional Governance

- Are the decision-making processes of water resource regulatory agencies reliable?
- Can irregular water use be detected?
- Can penalties be imposed?
- Are permits enforced?

Data Collection

- Is the hydrology system well documented?
- Is the hydrology data published?

Operational Rules

- Are the operational rules clear and well known?
- Are there mechanisms for water delivery in scarcity situations?
- Are there mechanisms that allow water trading?

Markets for Water Trading

- Are there (enough) buyers and sellers willing and able to trade?

Arrangements to deal with externalities

- Are the externalities evaluated?
- Are the externalities mitigated?

Source: FGV CERI

We recall that water resource management at the state level has varying degrees of maturity in the country. Therefore, the proposed assessment expresses an overview based on evidence and information provided by NWA but does not necessarily reflect the reality of the country as a whole.

5.1 Water Rights Regulatory Framework

Water rights are issued through permits so that they can be considered clearly defined. Moreover, water rights are dissociated from land rights. As already pointed out, water rights differ from property rights in an economic sense as the first is not tradable.

Barrier #1: Water permits are not tradable.

5.2 Institutional Governance

The lack of database integration and/or information sharing between federal and state management bodies often undermines the reliability of decisions in the permit granting process. As presented in Box 1, the NWA only recently began gathering information from some states in the REGLA system. However, there are still cases in which the state water regulators/agencies[15] resist sharing information databases with the NWA.

Water resource regulatory agencies monitor water uses under their jurisdiction to identify violations[16] and prosecute irregular users. The regulator establishes the water bodies in which users are required to implement a monitoring system. In such cases, the user must report their abstraction and discharge volumes through the Annual Water Use Statement (DAURH) on an annual basis. During inspections, this declaration is taken into consideration.

Beyond carrying out periodic inspections and checking complaints, water regulators detect irregular uses by proxy information, such as electric power usage. According to information provided by the NWA, water uses located in critical areas[17] are also monitored through satellite images on an annual basis. Although there are several ways of controlling irregular water uses, it is not possible to determine if all state regulatory bodies carry out the same types of inspections or with the same frequency. Also, given the extent of some basins, it is unlikely that all irregular uses can be detected. It is reasonable to claim that state agencies lack sufficient human capital and access to information on a reliable basis to properly audit and enforce the permits granted.

If any violation is identified, the irregular user is subjected to a penalty applicable through a due administrative process. Penalties are established in the 1997 Water Act for infringements in the management of federal rivers. However, the charged amounts are often considered insufficient to inhibit infractions. In the case of NWA, the agency prefers adopting educative measures rather than imposing penalties[18]. This indicates that the penalties previously pointed out are not regularly applied, at least not at the federal level.

---

[15] In some cases, the lack of information sharing between states and the federal regulator may lead to over allocation of water. This is a critical problem due to the dual jurisdiction in the allocation of water rights mentioned in section 3.2.
[16] Examples of violations include abstracting water without a permit, non-compliance with the permits' established conditions, as well as committing fraud on the declaration of consumed volumes.
[17] ANA (2013) presents the areas located in federal rivers where there is imbalance between water resource supply and demand of water. Those areas are called critical areas for water management.
[18] Information based on an interview a specialist from the National Water Agency.

The penalties for violations in state rivers are established in the legislation at the state level. In general, penalties are equal or more restrictive than those established for federal rivers.

Water rights enforcement problems can be assessed by two situations: (i) whether the permit can be declared void for any reason other than non-compliance to the pre-established conditions; and (ii) if the entry of a user or higher abstraction from an existing one can impair the right of a user.

As established in the Water Act, a permit may be partially or totally suspended in the following cases: (i) non-compliance with the pre-established conditions; (ii) absence of use for three consecutive years; or (iii) need of water to attend calamity situations, to prevent/reverse environmental degradation, to meet priority uses or to maintain conditions for navigational uses.

Water permits in Brazil are relatively insecure as suspensions due to any of the reasons indicated above do not entitle the user to any compensation. This increases the risk perception and undermines investment incentives. Also, the non-use of the permit may result in the partial or total suspension of it. This doctrine is known as “use it or lose it”.

The “use it or lose it” doctrine perpetuates the insecurity involved in water rights. If a water market is created and this doctrine continues to be followed, the risk perception for a potential buyer in the market increases. After a water trade is made, the water abstraction point may change. The potential risk then arises because the regulator supervises water use at the abstraction point defined on the permit. If the regulator is not notified of the abstraction point change, the regulatory body may understand that the user is not abstracting water anymore and, therefore, suspend the water permit. Hence, the notion/possibility of the suspension of a user’s rights in cases of non-use has to be addressed if the option is to implement markets for water (MATTHEWS, 2004).

As per the interference a new permit may have over an existing one without compensation, the lack of regular inspections makes it difficult to identify those interferences and, consequently to inhibit them. The risk of not having water available for a permitted user, due to the entry of a new one makes the water rights insecure.

Barrier #2: The "use it or lose it" doctrine is a potential limiting factor for the adoption of water markets as it limits the tradability of water rights.

5.3 Data Collection

The federal regulator collects and makes hydrological data available through the National Information System on Water Resources (SNIRH)[19]. The system also registers the valid permits issued by the NWA[20]. The collection and publication status of hydrological data by state agencies is not uniform. While some agencies make this information available on their websites, others make it available only upon request. This insufficient transparency of information is relatively common, as is the lack of registry standardization.

Barrier #3: The lack of transparency in information on water availability and valid water permits hinders the creation of water markets.

5.4 Operational Rules

The operational rules that users should follow are clearly stated on the water permits, including information about types of interference (e.g., abstraction), points of interference, validity period, quantity and general use conditions.

In Brazil, there is no established system to allocate water among multiple uses/users in cases of scarcity. The only priority is human and animal water consumption. For instance, if a drought occurs, each competent regulatory entity makes its own decision regarding the delivery of water. It can lead to an inefficient water allocation as no legal provision allows for water trading.

A new piece of legislation to amend the 1997 Water Act is under discussion in Congress[21]. It introduces water markets as an additional instrument for the management of water

---

[19] The data can be accessed through the following link: http://www.snirh.gov.br/

[20] The database of permitted users is called CNARH40. This system replaced the former CNARH database, which previously gathered information on users who did not hold permits.

[21] Proposed Legislation number 495/2017.

resources. The motivation for this proposal is the need to enact mechanisms to reallocate water from low value to high value uses.

The Proposed Legislation allows for monetary compensation between users located in the same basin or sub-basin for a certain amount of time. As transactions are restricted to the boundaries of the basin, the river basin committees would be responsible for preparing and submitting proposals for the creation of water markets in their area of competence to be approved by the granting authorities (NWA and state agencies). If approved, the river basin committees would operate markets, register water trading and provide information on demand, such as water availability and users interested in negotiating their rights.

Barrier #4: The Brazilian regulatory framework has no established mechanism to allocate water among multiple uses/users in cases of scarcity. The only priority is human and animal water consumption.

Barrier #5: The lack of definition of market instruments in the legal framework makes it difficult to implement them.

Barrier #6: The proposed legislation empowers river basin committees, which are bodies that already do not properly perform their current roles. Adding a new responsibility to this body can jeopardize the operation of the market.

5.5 Existence of Market for Water Trading

The existence of a potential market must be analyzed on a case-by-case basis. However, there may exist enough buyers and sellers that are willing to trade in areas where there are water conflicts. Some river basins have already been identified as suitable for implementing water markets on a pilot basis due to the heterogeneity of users' demands and/or to the "over allocation" of water in the basin (FGV EAESP and ANA, 2018). This is the case of the PCJ[22], Paraíba do Sul and São Marcos river basins.

[22] Piracicaba, Capivari and Jundiaí River Basins.

However, even if there exists a market for water trading, it may face resistance from users and society as a whole. This resistance is due to the lack of knowledge about how water markets work and what benefits they can bring once implemented.

Barrier #7: Social resistance due to the lack of knowledge about how water markets work and their benefits.

5.6 Existence of Arrangements to Deal with Externalities

The Proposed Legislation 497/2017 does not address the need for monitoring, mitigating or eliminating the possible effects and externalities on third parties.

Barrier #8: There is no provision for the monitoring and mitigation of externalities and effects on third parties in the current policy nor in the Proposed Legislation.

Table 3 summarizes the readiness assessment.

Table 3 - Water market readiness assessment - conclusions

Water Rights Regulatory Framework
• Water rights are clearly defined and dissociated from land rights, but it is not tradable;
Institutional Governance
• The lack of data integration between federal and state regulatory bodies hampers their decision-making processes reliability; • NWA has a robust monitoring process for detecting irregular water use in critical areas. As per state agencies, it is reasonable to claim that they lack sufficient human capital and access to information on a reliable basis to properly audit and enforce the permits granted; • There is legal ground for applying penalties under Brazilian law, however the imposed amounts are not sufficient to change user's behavior; • The "use it or lose it" doctrine is a potential limiting factor for the adoption of water markets as it limits the tradability of water rights.
Data Collection
• The lack of transparency in information on water availability and valid water permits hinders the creation of water markets.
Operational Rules
• There are clear operational rules established in water permits; • The Brazilian regulatory framework has no established mechanism to allocate water among multiple uses/users in cases of scarcity. The only priority is human and animal water consumption; • There is no definition of market instruments in the current legal framework, however there is a Proposed Legislation under discussion in Congress in order to allow the creation of water markets.
Markets for Water Trading
• Some river basins have already been identified as suitable for implementing water markets on a pilot basis; • There may have social resistance to the implementation of water markets due to the lack of knowledge about how water markets work and their benefits.
Arrangements to deal with externalities
• There is no provision for the monitoring and mitigation of externalities and effects on third parties in the current policy nor in the Proposed Legislation under discussion in Congress.

Source: FGV CERI

6. Policy Recommendations

As discussed in previous sections, the current institutional and regulatory framework have vulnerabilities that need to be addressed. This study presents the introduction of water markets in Brazil as a viable mechanism. Before water market implementation, some functional aspects need to be established to secure the proper functioning of the market, such as data collection and publicity, suitable market design and mechanisms to deal with scarcity situations. In parallel, it is important to focus on public opinion and to

disseminate the benefits of water market implementation. In fact, people tend to be resistant to change.

After identifying the barriers to the introduction of water markets in Brazil, we present policy recommendations to overcome these water market constraints. To address the barriers identified through the readiness assessment, we provide the following policy recommendations.

6.1. Promote greater understanding regarding the benefits of implementing water markets

The Ministry of the Environment – responsible for Brazilian water policy – should encourage more in-depth discussions and disclosure on the benefits of implementing water markets. Although water is a resource used by multiple users, most of the population do not know the rules governing its use. Any change in the status quo might face some resistance from society. However, users will be more likely to accept changes if they understand the following:

1. Water markets allow for the entry of new users and/or for the increase of consumption of users who already holds a permit, even in river basins in which water is fully allocated;
2. Markets bring economic rationality to the reallocation process. In times of water scarcity, markets provide flexibility to users as they no longer depend on administrative decisions on water allocation;
3. Water markets empower the user by giving them greater freedom of choice to respond to variations in water availability through voluntary transactions.

6.2. Standardize data collection

Regardless or not the establishment of water markets, an integrated water resource management system must have its information collected and published in a standardized and transparent way. Besides facilitating further evaluation and access of information for society, a solid database helps to coordinate information between state and federal agencies - the double dominion over water management in Brazil.

In the specific case of the water market, the standardization and publication of information are fundamental to facilitate the “matching process” between potential buyers and sellers, thus reducing transaction costs. Well-established markets generally present online platforms for trading, where information on the users willing to sell their rights, the prices and the amount of water transferred are available[23].

6.3. Approve water reform

As already mentioned, well defined and tradable property rights are essential for the creation of water markets. In Brazil, property rights have already been established through permits. However, permits differ from property rights in an economic sense as the formers are not yet tradable. Congress’ approval of the proposed legislation that allows permit trades is on the critical path for implementing water markets in Brazil.

Congress needs to properly discuss water reform in a way that the multiple water users can participate in this process. In addition, as water management must be developed in the river basin scale, water reform should establish general guidelines for market creation and leave more specific regulation to be defined at the local level.

6.4. Implement right incentives for water markets through an adequate legal and regulatory framework

In river basins, where water markets are implemented, the doctrine "use it or lose it" should be eliminated as it does not provide the correct incentive to promote water trades. This doctrine limits the market because the user may not be abstracting water at the point previously approved by the granting authority. This doctrine creates insecurity for the buyer/seller and makes the market unfeasible, due to the fact that at any moment a permit can be taken from its user – since the management body would not identify that the water is being abstracted elsewhere.

In any case, this doctrine is a perverse incentive, as it encourages the user “to use water regardless of his/her need, of the efficiency of its use or the potential consequences in

---

[23] For example, it is possible to check information about Australia’s Murray Darling trades in https://www.waterexchange.com.au/ .

medium and long term, in order to avoid the permanent loss of rights" (FGV EAESP and ANA, 2018).

6.5. Review water management mechanisms in times of scarcity

As water supply decreases during water shortages, it is necessary to reduce water demand, i.e., the volume allowed for use in each permit. As already mentioned, in situations of water scarcity, the only priority among multiple users is human needs and animal consumption. There is no rule to determine the allocation of water among other uses. Regardless of implementing water markets or not, it is necessary that the management bodies implement a rationing system. This system will guide decisions, such as which permitted users will receive water during water shortages and at what amount. The definition of a rationing system is a necessary condition for a water market to operate properly[24].

We list three alternative rules to deal with water scarcity:

- Use a proportional rationing system. In this system, water is delivered to all parties who hold rights, but at a proportionally reduced amount (MATTHEWS, 2004). It means that the probability of rationing is the same to all permit holders. From a market perspective, if the user wants to have access to his/her total volume, he/she should go to the market to buy the additional volume of water. So, water permit trades would promote the reallocation to the most efficient use;
- Use the chronological - or queuing - one. In this system, older permits are more secure than new ones. In other words, newer permits would be rationed before the older ones. The difference between that system and the previous one (proportional) is that permit holders face different probabilities of rationing. Again, water markets would be able to promote efficiency reallocation and permits market price would vary according to its risk of rationing.

[24] That is not a particular characteristic of the water market. Energy markets also deal with scarcity by means of management mechanisms. For instance, California Public Utilities Commission uses a set of complementary mechanisms – Interruptible Load Programs and Rotating Outage Program – to improve the reliability of California's electric system. The first one is a voluntary utility program in which large users agree willingly to reduce their electric usage on demand in return for a monetary payment or bill reduction. The Rotating Outage Program addresses (systematically and fairly) the need for forced reductions in electric use by curtailing electric service to customers when reductions obtained from the Interruptible Load Programs are not enough. For more details, see SEUC (2001).

- Issue permits with different probability of attendance/water delivery. For example, three preference categories could be created: (i) category 1 is entitled to receive water 90% of the time; (ii) category 2, 50% of the time; and (iii) category 3, 20% of the time. It is essential to properly know river basin hydrological data to make this system possible. That would require a change in the Brazilian permit granting process as currently no such thing exists.

6.6. Study water market designs

The development of water markets must be analyzed on a case-by-case basis. Once the government identifies an area of interest, further studies may be needed to develop a proper market design for that basin. For a sense of this, we discuss in this paper a potential water market for the São Marcos River Basin.

The definition of rules for water trading is one of the steps of water markets design. These rules should consider local characteristics, such as the existence of delivery infrastructure. The involvement of water users during the process of defining those rules is also essential, so they can comprehend how the market will work and provide support or objective comments.

The water market design should also consider how potential externalities would be mitigated, since changing the point of diversion, the point of return flow or the place of water use can impact on the water availability to other users. An option to address this problem and to guarantee water to downstream users is to maintain the return flow of water by allowing only the consumptive permitted volume to be traded.

It is worth stressing that any market design requires institutional strengthening. There should be a proper independent and technical body to monitor water use and approve trades, as well as evaluate and control third parties impacts.

6.7. Select suitable areas to host pilot markets for water permits trading

Where there is an imbalance between water supply and demand or when a river basin is fully allocated, water markets emerge as a suitable economic instrument to deal with water scarcity and to promote its reallocation.

Even though international experiences provide a solid benchmark to design water markets in Brazil, local characteristics must also be taken into account. As it is a new economic instrument for the country's water management system, it may face some resistance. Pilot markets in Brazilian river basins are key to solve water users' doubts and to test water market performance. In section 7 we present São Marcos River Basin case study. We suggest a possible water market design and its potential gains.

7. São Marcos River Basin Case Study

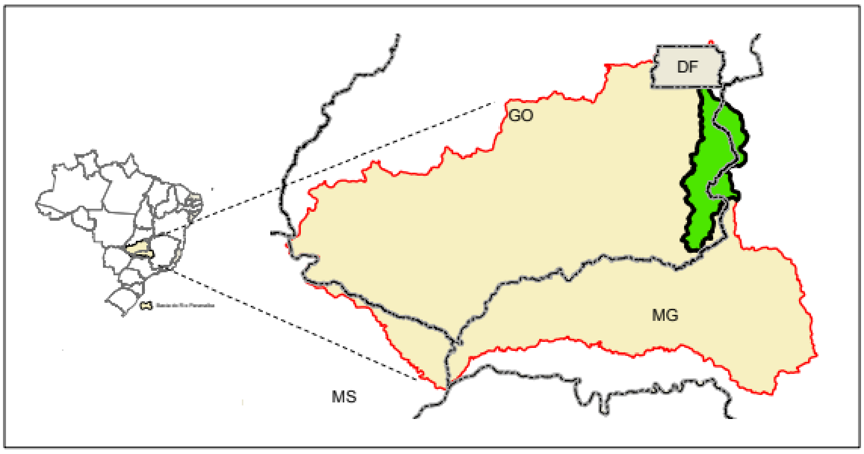
The São Marcos River Basin (SMRB) is a small river basin that is part of the Paranaíba River Basin. The São Marcos River is a federal river, as it is a border between the states of Goiás and Minas Gerais (Figure 8). There is a current conflict between agriculture and hydroelectricity generation in the SMRB upstream area due to over-allocation and over-use of water resources. According to the HPP's permit, the allowed water consumption upstream from the Batalha HPP is equal to 9,42 m^3/s. However, NWA estimates that the water demand for irrigation purposes in the same area equals to 10.78 m^3/s.

The decision to focus on this conflict is threefold. First, the two competing sectors have important roles in the Brazilian economy and conflicts like this may also occur in other river basins[25]. Second, this conflict was identified in 2010, and since then it has been worsening. Additionally, the importance of agriculture in the region demonstrates that the existing conflict between the two user sectors may arise in the future among the irrigators

[25] For example, there is also a conflict between agriculture and hydroelectricity generation in Preto River, which is a tributary of Paracatu River. Preto River is also a federal river as it is a border between the states of Goiás and the Federal District. See more in Machado (2009).

themselves. Finally, the SMRB is one of the critical areas for water management as defined by NWA[26].

Figure 8 – The São Marcos River Basin's Location



Source: ANA (2013b).

Bellow, we present the main characteristics of the two competing users in SMRB – agriculture and hydroelectricity generation. Then, we describe the background of the conflict. Finally, we discuss the water market potential by estimating its gains.

7.1 Agriculture in the SMRB

The SMRB, especially its upstream area (known as Alto São Marcos), has a well-developed agricultural activity. One should recall that the municipality of Cristalina, GO, is located within the SMRB and it presents the largest agricultural GDP in Brazil with approximately 600 million Brazilian Real (BRL) (IBGE, 2010).

In the SMRB there are approximately 104,828 hectares of irrigated area and 1,273 central pivots. Central pivots are the most widely used irrigation technique in the region (ANA, 2017b). From this total irrigated area, 82,906 hectares (79%) and 1,011 central pivots are located in Alto São Marcos (upstream from the Batalha HPP).

7.2 Hydroelectricity generation in the SMRB

The Batalha HPP is a hydroelectric power plant located on the São Marcos River, specifically on the border between the municipalities of Cristalina, in the state of Goiás,

[26] See footnote 12.

and Paracatu, in the state of Minas Gerais. The plant is located upstream from the Serra do Facão HPP, also located on the São Marcos River. The Batalha HPP has 52.5 MW of installed capacity. Despite its low power capacity, Batalha's reservoir regulates the river flow and allows for energy gains through the cascade of plants located in the Paranaíba River (Figure 9).

Figure 9 - HPPs located in Paranaíba River Basin

Source: CBH-Paranaíba (2018a).

7.3 SMRB water conflict background

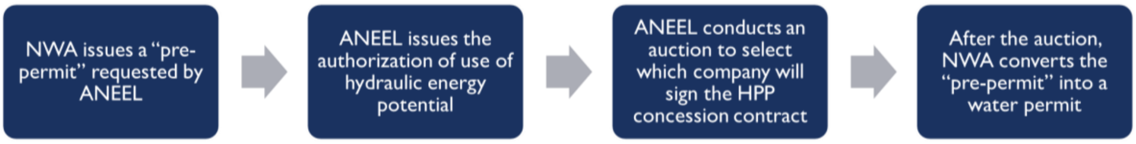
The permit granting process for hydroelectricity generation purposes differs from the one presented in Figure 3 as it depends on the authorization of use of two natural resources: water resource and hydraulic energy potential. The former is under the authority of NWA, while the latter is under the National Electric Energy Agency (ANEEL).

First, NWA has to enact a "pre-permit"[27] so that ANEEL can issue the authorization of use of hydraulic energy potential. The "pre-permit" sets up the available flow for

[27] In Portuguese the "pre-permit" is called *Declaração de Reserva de Disponibilidade Hídrica* (DRDH). It is a document that precedes the permit in the case of hydroelectricity generation. After the auction organized by the National Electric Energy Agency (ANEEL), the DRDH is converted into a water permit.

consumptive uses (e.g., irrigation) upstream from the plant until the end of the concession. After that, ANEEL conducts an auction to select the company that will sign the concession to explore the HPP. Figure 10 summarizes the permit granting process for hydroelectricity generation purposes.

Figure 10 - Permit granting process for hydroelectricity generation purposes



Source: FGV CERI.

In the case of SMRB, NWA enacted Batalha HPP's "pre-permit" in 2005. The auction conducted by ANEEL occurred in that same year, and Furnas-Centrais Elétricas won it. In 2008, NWA converted the "pre-permit" into a water permit, which included the same restrictions on the water consumption upstream from the Batalha HPP as the "pre-permit" (ANA, 2008).

In 2010, the monitoring of irrigated areas conducted by NWA revealed that the existing consumption upstream from the Batalha HPP had already approached the limit fixed for 2040 (end of concession). NWA also identified that the increasing agriculture in the Alto São Marcos area could impact the electricity generation of the plants located downstream in the basin. Knowing about this conflict between irrigators and the electricity sector, NWA conducted a series of studies and inspections.

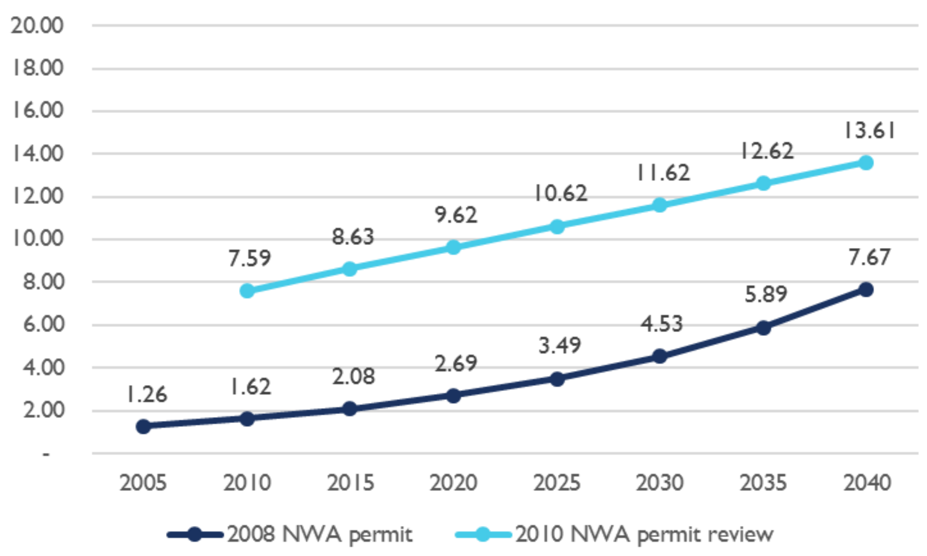
First, the regulatory agency estimated the economic value of water in the SMRB. This study revealed that irrigation had a higher value use, indicating potential gains from reallocating water in favor of agriculture (ANA, 2010b). Then, the NWA published the SMRB Water Resource Framework[28] aiming to propose a water reallocation strategy for the river basin (ANA, 2010c). This proposal led to the Batalha HPP's permit revision in

[28] A Water Resource Framework is a set of rules for the use of water resources. It is defined by the granting authorities in coordination with water users and the involved river basin committees. Developing a Water Resource Framework is necessary among other cases when there is an already existing, or potential, conflict.

2010 (ANA, 2010d). The NWA increased the upstream consumption flow's limit, as presented in Figure 11.

Consequently, Batalha's physical guarantee reduced. According to the electric sector's legislation[29], the 2010 review could only decrease to a maximum of 10% of Batalha's physical guarantee. Thus, Batalha's HPP permit was amended so that the maximum reduction would be reached only in 2040.

Figure 11 - Limits of consumptive uses upstream from Batalha HPP



Source: FGV CERI

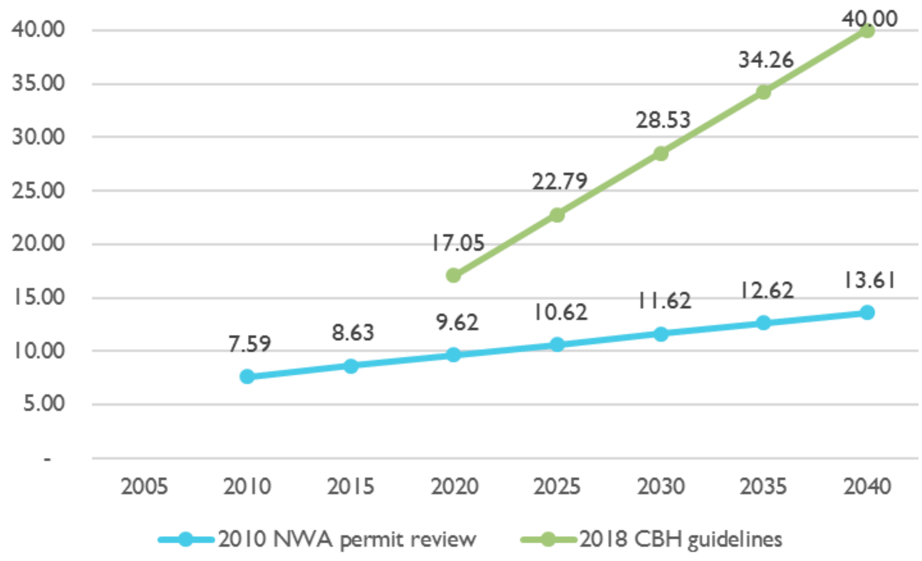
Even though NWA has increased the allowed consumption flow upstream from Batalha HPP, it would not be sufficient to meet the irrigation water demand. According to a NWA's projection and based on the evolution observed between 1986 and 2011, the basin would reach 205,000 hectares of irrigated areas in 2040. It would reach 170,000 hectares of irrigated area upstream from the Batalha HPP. If we consider the irrigators' average standard consumption[30], this area will correspond to a consumptive flow of 22.1 m³/s. This would exceed the limit fixed for 2040 by more than 60%.

[29] Article 21 of Decree nº 5555/1998 established that the physical guarantee of each plant may be revised every five years so as not to imply a reduction of more than 5%. However, the reductions are limited to 10% of the basic amount as stated in the concession agreement during its term.

[30] According to ANA (2010b), the irrigators' average standard consumption in SMRB is 0.13 L/s/ha.

With the previous information in mind, in 2016, the Paranaíba Basin Committee[31] (CBH Paranaíba) defined that irrigation would be the priority use upstream from the Batalha HPP (CBH-PARANAÍBA, 2016b). Two years later, based on this statement, the CBH Paranaíba published guidelines for the water resource regulatory agencies (NWA, Minas Gerais state agency and Goias state agency) to increase the water flow for irrigation purposes upstream from the Batalha HPP (Figure 12) (CBH-PARANAÍBA, 2018). It is still uncertain if this suggestion will result in a formal review of Batalha's permit. Until this moment the NWA has not revised it yet.

Figure 12 - Limits of consumptive uses upstream from the Batalha HPP

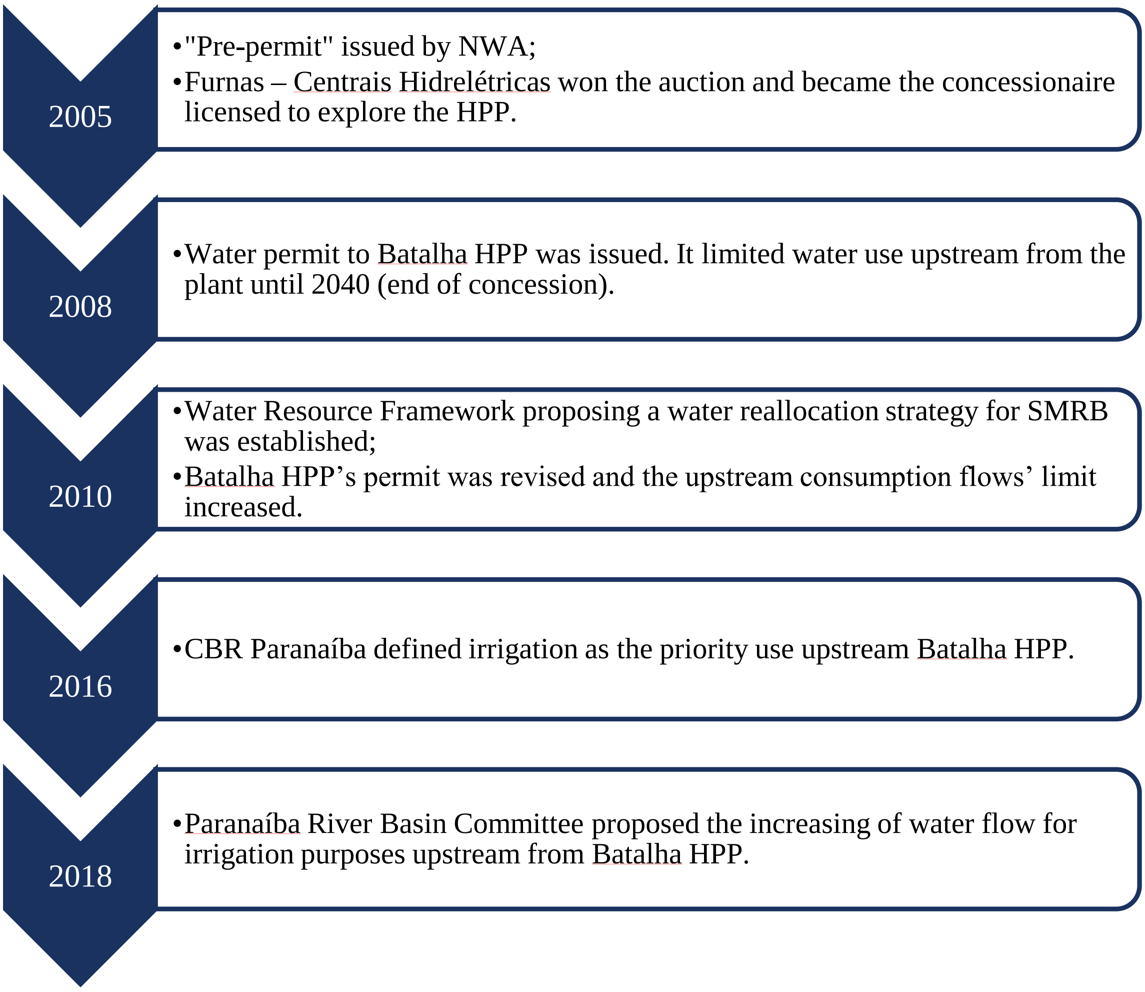


Source: FGV CERI

The timeline presented in Figure 13 summarizes the dispute between irrigators located upstream from the Batalha HPP (Alto São Marcos area of SMRB) and the Batalha HPP.

[31] São Marcos River flows to Paranaíba River, so Paranaíba River Basin Committee also covers São Marcos River area.

Figure 13 - Timeline



Source: FGV CERI

As presented, there is an imbalance between water demand and supply in SMRB. Thus, we believe that the creation of a water market could help to deal with this problem.

7.4 The size of SMRB potential water market

As already mentioned, two sectors are competing for water in the upstream area of the SMRB: hydroelectricity generation and irrigation. To simplify the analysis, we suppose that the market would be limited to trades among irrigators[32]. Future analyzes shell include other uses such as power generation. In fact, problems such as the 2014 water

[32] OECD (2015) also suggests this water market design.

shortage in São Paulo[33] highlight the need for an approach that includes the hydroelectric generator.

Both federal and states agencies manage SMRB water resources. In fact, more than 80% of the water uses in SMRB occur in state rivers. As information of users permitted by state agencies was not available[34], the analysis of this paper is limited to users granted by NWA. More than 80% of the water uses in SMRB occur in state rivers. Therefore, the sample of market players that we consider is much lower than what exists.

Table 4 presents the valid permits issued by the NWA for irrigation purposes and their main characteristics[35]. In-depth analysis to estimate the size of the market requires access to information on permits issued by state agencies.

Table 4 – Current NWA permitted users in Alto São Marcos

Irrigator	Permit Resolution	Annual Volume (m³)	Irrigated Crop	Irrigated Area (ha)	Estimated Irrigation Period[36]
1	402/2015	240,200	Bean	50	March-July
2	452/2015	1,302,841	Corn	197.4	May-Oct
3	212/2016	1,881,659	Corn	260	May-Sept
4	263/2016	1,785,000	Soybean	185.2	April – Oct
5	781/2016	1,606,050	Corn	213	May-Sept
6	816/2017	748,440	Corn	104	April-Sept
7	1156/2017	1,957,890	Corn	244.5	May-Sept
8	1468/2017	698,850	Bean	125	April-Oct
9	1492/2017	1,443,960	Bean	150	March-Sept
10	2210/2017	257,418	Bean	34	May-Sept
11	304/2018	652,344	Bean and corn	77	May-Oct
12	1044/2018	601,990	Soybean	80	Jan-Dec
	Total water volume (m³)	**13,800,342**	**Total irrigated area (ha)**	**1,720.10**	

[33] In 2014 the National System Operator (in Portuguese, *Operador Nacional do Sistem*a - ONS) lowered the Ilha Solteira Reservoir's quota to a level lower than the minimum quota of 325.40 meters established as an operating constraint to guarantee navigation level. This occurred because ONS decreased the outflow of HPPs located upstream from the Ilha Solteira HPP in order to fill up their reservoirs. As a result, navigation was interrupted for 20 months (from May 2014 to January 2016). Shipping companies estimate that the negative economic impact caused by this action was over R$ 200 million (GLOBORURAL, 2016).

[34] The information provided by Goiás State agency was insufficient to meet the goals of this paper. Distrito Federal and Minas Gerais States agencies have not responded to the information request until the deadline of this project.

[35] There are 10 more permits in Alto São Marcos, however it lacks information about annual volume and/or monthly permitted volume. The permit resolutions are: 1355/2013; 1005/2015; 647/2016; 318/2017; 65/2018; 691/2018; 1296/2018; 1439/2018; 1673/2018; and 1996/2018.

[36] We analyzed the monthly permitted volume to estimate the irrigation period.

Source: ANA

7.5 Estimating water value in SMRB

To understand how water market among the irrigators would work we calculate/estimate the water economic welfare for each permitted irrigator (Table 4). We adopted the residual imputation approach, as suggested by Young (1996). The author states that this is the most frequently used approach to apply shadow pricing for irrigation water. NWA has also adopted a similar approach to calculate the water value in the upstream area of SMRB.

The residual imputation approach

The microeconomics involved in the maximization of irrigator's profit is as follows:

$$\max_{(x_1,\dots,x_n,x_w)} \left\{ P \cdot f(x_1, \dots, x_n, x_w) - P_w \cdot x_w - \sum_{i=1}^{n} P_i \cdot x_i \right\} \quad (1)$$

Where P represents the price of the crop; f is the production function; P_i is the price of the production factor i; x_i represents the quantity of production factor i (e.g., labor, land, etc.); P_w is the price of water; and x_w is the quantity of water.

On the assumption that crops and all production factors markets are perfectly competitive, prices may be treated as constants. We get, by applying the first order condition for each production factor:

$$P_w = P \cdot \frac{\delta f}{\delta x_w} \quad (2)$$

$$P_i = P \cdot \frac{\delta f}{\delta x_i} \quad (3)$$

It means that the price of water or any other production factor is equal to its value, that is, the value of the marginal productivity of each factor.

If the production function f is homogeneous in the first degree (i.e., f(tx)=tf(x)), we can apply Euler's theorem (compute the first derivative with respect to t and evaluate it at t=1). So, the production functions can be written as:

$$f(x_1, \ldots, x_n, x_w) = x_w \frac{\delta f}{\delta x_w} + \sum_{i=1}^{n} x_i \cdot \frac{\delta f}{\delta x_i} \quad (4)$$

Multiplying (4) by P and substituting it with (2) and (3), we may obtain:

$$P_w = P \cdot \frac{\delta f}{\delta x_w} = \frac{P \cdot f(x_1, \ldots, x_n, x_w) - \sum_{i=1}^{n} P_i \cdot x_i}{x_w} \quad (5)$$

So, in the residual imputation approach, the value of the marginal productivity of water (or water value) is the difference between the revenue and the expenses of the crop production divided by the water consumption.

SMRB data

As presented in Table 4, we have information about water demand, irrigated area, cultivated crop as well as irrigation period for permitted users located in Alto São Marcos. We use the valid permits issued by NWA to estimate the water's economic welfare for each irrigator. It consists of calculating the net income of the irrigator per volume of water.

To estimate the irrigator's revenue per area (ha), we multiply crop productivity (kg/ha) by the irrigated area (ha) and by the crop price (R$/kg). The productivity of bean, corn, and soybean produced in the SMRB is presented in Table 5[37]. We access information on irrigated areas directly from the permits issued by NWA. Crop prices were then checked on the Agrolink website[38] on February 25th, 2019 (Table 5).

Table 5 - Crop average productivity adopted to SMRB irrigated areas and its price

Crop	**Average Productivity (kg/ha)[1]**	**Price (R$/kg)[2]**	**Revenue per area (R$/ha)**
Bean	3,000	0.52	1,560
Corn	10,250	1.14	11,685
Soybean	3,300	4.13	13,629

[37] Information based on ANA (2010). This study considered the productivity estimated by Machado (2009).
[38] Available at https://www.agrolink.com.br/ .

Source: [1]ANA (2010b); [2] Agrolink website

To estimate crop expenses, we use the average costs of production presented in Machado (2009) and also adopted by NWA's in its study of water value in the São Marcos River. Crop expenses (total cost) are calculated by adding the costs of inputs and services to the central pivot[39] depreciation and energy expenses. The inputs and services include seeds, fertilizers, planting, and harvest. We adjust the costs of inputs and services using the inflation index[40] (Table 6).

Table 6: Crop's inputs and services costs

Crop	Input and Services Cost (R$/ha)
Bean	2,869.76
Corn	2,378.45
Soybean	3,474.94

Source: ANA (2010b) and Machado (2009), adjusted by IGPM

According to ANA (2010b), the annual depreciation costs are R$ 565.84/ha and energy costs are equal to R$ 152.96/1,000 m^3. Both costs have also been adjusted for inflation[41].

The number of productive cycles practiced by each irrigator during a year is also a relevant variable because it affects both revenue and crop expenses. We estimate the number of annual cycles based on the period of irrigation.

The value of the marginal productivity of water as a proxy for water value is then estimated for each permitted user (Table 7).

[39] Central pivot is the irrigation technology used in the SMRB.
[40] We adjusted the prices by the General Market Price Index (IGPM) using the Citizen Calculator available at https://www3.bcb.gov.br/CALCIDADAO/publico/exibirFormCorrecaoValores.do?method=exibirFormCorrecaoValores
[41] See footnote 39.

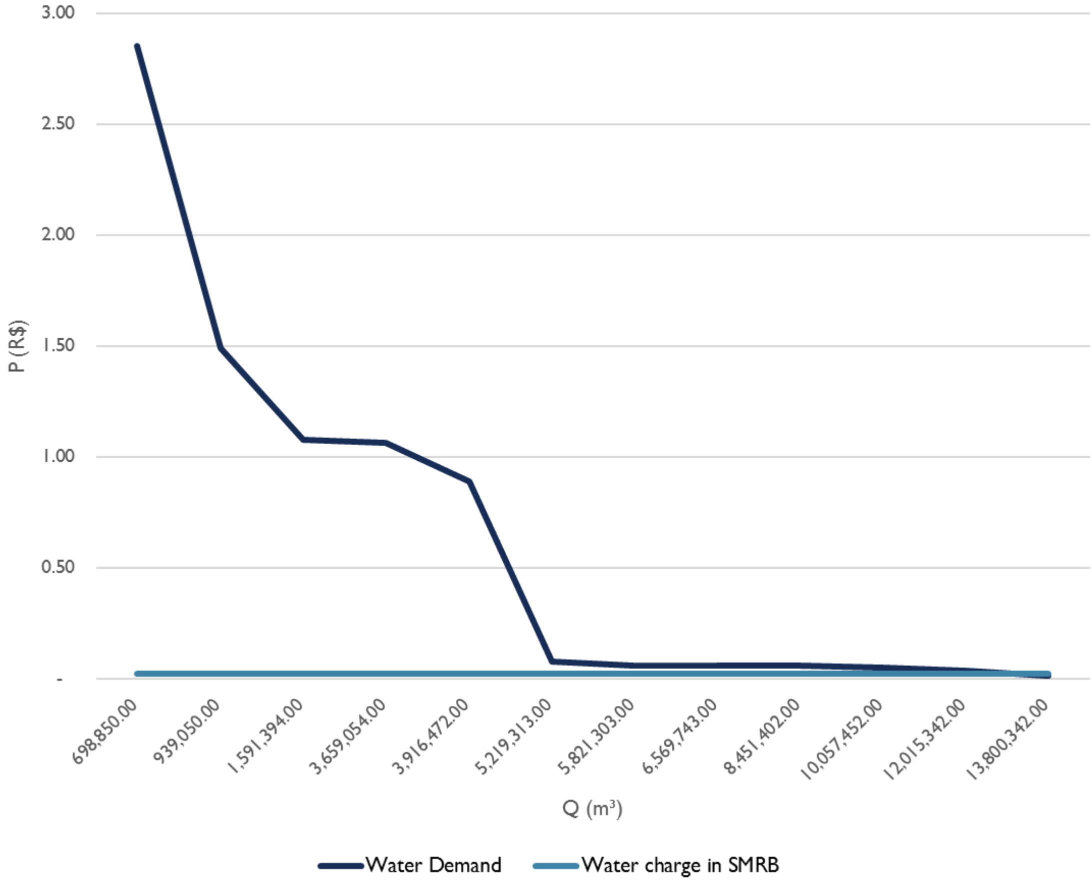
Table 7 - Economic benefits of each irrigator in São Marcos River

Irrigator	Permit Resolution	Annual Volume (m³)	Irrigated Crop	Irrigated Area (ha)	Irrigation Period	Productive Cycle	Gross Revenue (R$)	Production Expenses (R$)	Net Revenue (R$)	Value of marginal productivity/water value (R$/m³)
9	1468/2017	698,850	Bean	125	April - Oct	2	3,097,508.75	1,104,224.61	1,993,284.14	2.85
1	402/2015	240,200	Bean	50	March-July	1	619,501.75	261,665.43	357,836.32	1.49
12	304/2018	652,344	Bean and corn	77	May-Oct	2	1,364,292.74	661,865.36	702,427.37	1.08
10	1492/2017	2,067,660	Bean	150	March-Sept	2	3,717,010.50	1,523,731.56	2,193,278.94	1.06
11	2210/2017	257,418	Bean	34	May-Sept	1	421,261.19	193,139.91	228,121.28	0.89
2	452/2015	1,302,841	Corn	197.4	May-Oct	1	1,051,757.56	951,419.60	100,337.96	0.08
13	1044/2018	601,990	Soybean	80	Jan-Dec	3	899,071.80	864,395.26	34,676.54	0.06
7	816/2017	748,440	Corn	104	April-Sept	1	554,117.46	511,282.56	42,834.90	0.06
3	212/2016	1,881,659	Corn	260	May-Sept	1	1,385,293.65	1,279,913.16	105,380.49	0.06
5	781/2016	1,606,050	Corn	213	May-Sept	1	1,134,875.18	1,058,976.01	75,899.17	0.05
8	1156/2017	1,957,890	Corn	244.5	May-Sept	1	1,302,708.84	1,234,064.72	68,644.11	0.04
4	263/2016	1,785,000	Soybean	185.2	April - Oct	2	2,081,351.22	2,064,339.82	17,011.39	0.01

Source: FGV CERI.

Based on these results we can construct the theoretical factor demand function for water. The inverse demand for water (i.e., its quantity as a function of its price) is presented in Figure 14.

Figure 14 - Theoretical factor demand function for water



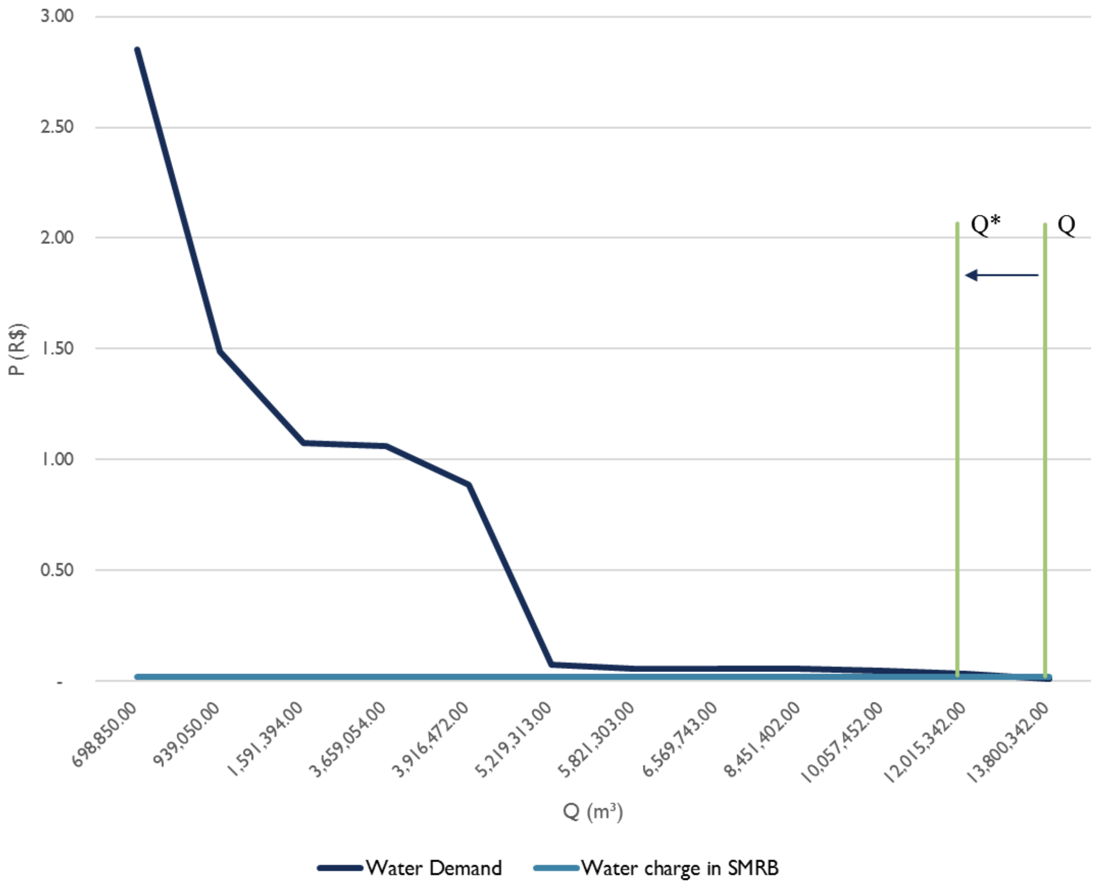
Source: FGV CERI.

We also present in Figure 14 the water charge in SMRB to confirm two remarks pointed out in section 3.4: (i) water charge is very low in scarcity situations, in this case, in situations when water availability is lower than 5,200,000 m³. Until this limit, the water charge is much lower than the users' willingness to pay for water. As a consequence, the charged value does not drive users behavior; and (ii) water charge in Brazil is not an economic tool for managing water resources as it does not signal to users the real water value.

As the water available in the SMRB is fully allocated, this analysis assumes that the water supply is equal to the total permitted flow (point Q in Figure 15). We suppose that in a certain period, water supply is not enough to deliver water to all permitted users. This situation requires the regulator – NWA – to limit water consumption at a level, let's call

it Q* (Figure 15). In a competitive market, the more productive firms would be willing to pay a price P* that equates demand to offer, that is, P* solves $Q^d(P^*)=Q^*$.

Figure 15 – Simulation of regulator reducing the water supply in a scarcity situation



Source: FGV CERI.

Simulating the gains of creating a water market

Our hypothesis to simulate the gains of creating a water market is that the regulator restricts the use of water that generates an excess demand of 30% with prices set to zero.

We simulate two cases to compare the possible benefits of a water market. In the first case, we consider that a proportional reduction in water availability is imposed on all users. That is, we consider that all users suffer a 30% restriction in the use of water. We call it a proportional rationing system.

The second case is the worst-case scenario one. In this simulated environment, we consider that the lower productive firms concentrate the rights to use water, and the most productive ones have to restrict their use in favor of the less productive ones. Note that,

this is an extreme case for sure, but a “first come, first served” approach may result in scenarios like the one considered here.

In both cases, we compute the producer surplus and compare it with the benchmark case where there is a competitive market allowing for water permits trading.

The total surplus with no water rationing is just the sum of all positive net revenue which is R$ 5,919,733.00. With no water rationing, the total demand for water is 13,800,342 m^3. In the simulated environment, there is a restriction of 30% in water use, and the total water supply equals 9,660,239.40 m^3.

In the competitive benchmark case, the equilibrium price of water is R$ 0.05 – i.e., the point where the water supply curve (fixed water availability) crosses the demand curve In this scenario, the total surplus equals to R$ 5,769,698.00 (Table 8).

Table 8 - Results of the competitive benchmark scenario

Irrigator	**Volume of Water (m^3)**	**Accumulated Volume (m^3)**	**Value of marginal productivity (R$/$m^3$)**	**Surplus (R$)**
8	698,850	698,850	2.85	1,993,284
1	240,200	939,050	1.49	357,836
11	652,344	1,591,394	1.08	702,427
9	2,067,660	3,659,054	1.06	2,193,279
10	257,418	3,916,472	0.89	228,121
2	1,302,841	5,219,313	0.08	100,338
12	601,990	5,821,303	0.06	34,677
6	748,440	6,569,743	0.06	42,835
3	1,881,659	8,451,402	0.06	105,380
5	1,208,837	9,660,239	0.05	11,520.45

Source: FGV CERI.

An important result from this benchmark case is that, besides the reduction of 30% in the use of water, if a market for water exists and works competitively, the total loss of welfare is only 2.5% or R$ 150,034.22. That occurs because the competitive framework ensures that the rationing affects only the less efficient producers. These producers reduce their production, but they are financially compensated for that.

On the other hand, if the proportional rationing is adopted, the reduction of 30% in the use of water will fall into all the producers, including the most efficient ones. Considering constant returns to scale, this scenario would ultimately reduce the total surplus in an

amount of exactly 30% to a total of R$ 4,143,812.83 or a total reduction of R$ 1,775,919.78.

The worst case scenario would be if the 30% reduction in the use of water only impacts the most productive one. In this case, the total surplus of the 70% less efficient producers is only R$ 427,561.71 which accounts for a reduction of 92.8% from total welfare (Table 9).

Table 9 - Results of the worst case scenario

Irrigator	Volume of Water (m^3)	Accumulated Volume (m^3)	Value of marginal productivity (R$/$m^3$)	Net Revenue (R$)
4	1,785,000	1,785,000	0.01	17,011.39
7	1,957,890	3,742,890	0.04	68,644.11
5	1,606,050	5,348,940	0.05	75,899.17
3	1,881,659	7,230,599	0.06	105,380.49
6	748,440	7,979,039	0.06	42,834.90
12	601,990	8,581,029	0.06	34,676.54
2	1,079,210	9,660,239	0.08	83,115.11

Source: FGV CERI.

Table 10 summarizes the total surplus and total loss of welfare of each simulated scenario.

Table 10 - Comparison between the simulated scenarios

Scenario		Total Surplus (R$)	Total loss of welfare
No rationing		5,919,733	-
30% rationing	Competitive benchmark	5,769,698	-2.5%
	Proportional rationing	4,143,812.83	-30.0%
	Worst-case scenario	427,561.71	-92.8%

Source: FGV CERI.

The potential benefits of a water market are astonishing in the SMRB since the value of the marginal productivity of water in the river basin varies at least from 0.01 to 2.85 R$/$m^3$.

8. Conclusion

Conflicts over water use is a reality in many areas across Brazil. These conflicts tend to be accentuated by climate change and by the soaring demand. The Brazilian regulatory

framework does not count on mechanisms capable of promoting an efficient reallocation of water. Thus, the existing mechanisms for addressing water scarcity are inefficient. This paper examines the desirability and feasibility of creating water markets to incentivize the reallocation of water towards its highest value use.

The first-principles analysis shows that water markets may dominate water pricing mechanism. The conducted readiness assessment identifies some legal and institutional barriers to the creation of water markets in Brazil. It means that further reforms are required to design and implement efficient water markets. Policy recommendations are then provided to overcome the barriers identified in our analysis.

Aiming to assess the potential gains from the implementation of water markets in Brazil, we simulate a market for irrigators located in the São Marcos River Basin. Assuming that the regulator restricts the use of water that generates an excess demand of 30% with prices set to zero, we find that if a proportional rationing system is applied, total loss of welfare would equal to 30%. However, if a market for water exists and works competitively, we estimate that the total loss of welfare would be only 2.5%. The case study highlights how the creation of a water market can lead to an efficient allocation and increase social welfare.

9. References

ANA (2008). Agência Nacional de Águas. "*Resolução nº 489, de 19 de agosto de 2008*". Available at: http://arquivos.ana.gov.br/resolucoes/2008/489-2008.pdf

___. (2010a). "*Relatório 2009 Cobrança pelo uso dos recursos hídricos na bacia do Paraíba do Sul*".

___(2010b). "*Nota Técnica nº 103, de 30 de agosto de 2010*".

___(2010c). "*Nota Técnica nº 104, de 30 de agosto de 2010*". Available at: http://www3.ana.gov.br/portal/ANA/todos-os-documentos-do-portal/documentos-sre/marcos-regulatorios/nt-sao_marcos.pdf.

___(2010d). "*Resolução nº 564, de 25 de outubro de 2010*".

___(2013). "*Portaria n° 62, de 26 de março de 2013*".

___(2015). "*Conjuntura Recursos Hídricos Brasil*".

___(2017a). "*Atlas Esgotos: Despoluição de Bacias Hidrográficas*". Available at http://arquivos.ana.gov.br/imprensa/publicacoes/ATLASeESGOTOSDespoluicaodeBaciasHidrograficas-ResumoExecutivo_livro.pdf

___(2017b). "*Conjuntura dos Recursos Hídricos no Brasil 2017*." Available at http://www3.snirh.gov.br/portal/snirh/centrais-de-conteudos/conjuntura-dos-recursos-hidricos/conj2017_rel_ingles-1.pdf.

___(2019). "*Manual de Usos Consuntivos de Água no Brasil*". Available at http://www.snirh.gov.br/portal/snirh/centrais-de-conteudos/central-de-publicacoes/ana_manual_de_usos_consuntivos_da_agua_no_brasil.pdf .

Australian Bureau of Agricultural and Resource Economics and Sciences (2018). Surface water allocation trade, 2016-17. Available at https://public.tableau.com/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci#!/vizhome/AustralianWaterMarketsDashboard2016-17/AWMR2016-17

Australian Competition and Consumer Commission (2016). Review of the Water Charge Rules Final Advice. Available at http://www.agriculture.gov.au/SiteCollectionDocuments/water/final-advice.pdf

Australian Government (2018). Water Act 2007. Available at https://www.legislation.gov.au/Details/C2018C00247

Cantin, B., Shrubsole, D., & Aït-Ouyahia, M. (2005). "Using economic instruments for water demand management: Introduction". Canadian Water Resources Journal, 30(1), 1-10.

CBH-Doce. (2018). "*Deliberação CBH-Doce nº 69, de 12 de junho de 2018"*. Available at: http://www3.ana.gov.br/portal/ANA/todos-os-documentos-do-portal/documentos-sas/arquivos-cobranca/deliberacao-cbh-doce-no-69_18.pdf

CBH-PARANAÍBA. (2016a). "*Deliberação nº 61, de 10 de março de 2016*".

__________________ (2016b). "*Deliberação nº 70, de 15 de dezembro de 2016*".

__________________. (2018). "*Deliberação nº 88, de 27 de março de 2018*".

CBH-Verde Grande (2015). "*Deliberação n° 50, de 5 de maio de 2015*".

CBHSF. (2016). "Plano de Recursos Hídricos da Bacia Hidrográfica do Rio São Francisco 2016-2025".

_______. (2017). "*Deliberação nº 94, de 25 de Agosto de 2017*".

Easter, K. W., Rosegrant, M. W., & Dinar, A. (Eds.). (1998). "Markets for water: Potential and performance". Springer Science & Business Media.

EPE (2018). *Matriz energética e elétrica*. *Empresa de Pesquisa Energética*. Available at http://epe.gov.br/pt/abcdenergia/matriz-energetica-e-eletrica .

Fernandes, R. D. O., Silveira, C. D. S., Studart, T. M. D. C., & Souza Filho, F. D. A. D. (2017). "Reservoir yield intercomparison of large dams in Jaguaribe Basin-CE in climate change scenarios". RBRH, 22.

FGV EAESP, ANA. (2018). "Instrumentos econômicos aplicados à gestão de recursos hídricos: caminhos para sua adoção em situações de conflito pelo uso da água no Brasil". Available at: https://www.researchgate.net/publication/328432690_Instrumentos_economicos_aplicados_a_gestao_de_recursos_hidricos_caminhos_para_sua_adocao_em_situacoes_de_conflito_pelo_uso_da_agua_no_Brasil.

FGV EESP. (2016). Available at https://bibliotecadigital.fgv.br/dspace/bitstream/handle/10438/17675/Efici%C3%AAncia_do_Uso_da_%C3%81gua_no_Brasil_Relat%C3%B3rio_Completo.pdf.

GloboRural (2016). Available at: https://revistagloborural.globo.com/Rios-do-Agro/noticia/2016/05/apos-quase-dois-anos-hidrovia-do-rio-tiete-retoma-transporte-de-cargas-2.html.

Grafton, Q. and Peterson, D. (2007). Water trading & pricing, in Hussey, K. and Dovers, S.(eds), Managing Water for Australia: The Social and Institutional Challenges. CSIROPublishing, Collingswood, Victoria, pp. 73–84.

Grafton, R. Q., Landry, C., Libecap, G. D., McGlennon, R., O'Brien, R. J. (2010a). "An integrated assessment of water markets: Australia, Chile, China, South Africa and the USA". National Bureau of Economic Research.

Grafton, R. Q., Landry, C., Libecap, G. D., O'Brien, R. J. (2010b). "Water markets: Australia's Murray-Darling basin and the US Southwest". National Bureau of Economic Research.

Grafton, R. Q., Libecap, G. D., Edwards, E. C., O'Brien, R. J., & Landry, C. (2012). "Comparative assessment of water markets: insights from the Murray–Darling Basin of Australia and the Western USA", Water Policy, 14(2), 175-193.

Kelman, J. (2009). "*Desafios do regulador*". Synergia: Centro de Estudos Económicos do Setor Energêtico.

Machado, B. G. F. (2009). "*Análise econômica aplicada à decisão sobre alocação de água entre os usos irrigação e produção de energia elétrica: o caso da Bacia do Rio*

Preto". Master's thesis in Environmental Technology and Water Resources at Universidade de Brasília.

Matthews, O. P. (2004). "Fundamental questions about water rights and market reallocation". Water Resources Research, v. 40, n. 9.

Murray–Darling Basin Authority (2018). Website available at https://www.mdba.gov.au/

OECD (2015). "Water Resources Governance in Brazil". OECD Studies on Water.

OECD (2017). "Water Charges in Brazil: the ways forward". OECD Studies on Water.

Rosegrant, M. W., & Gazmuri S, R. (1995). "Reforming water allocation policy through markets in tradable water rights: lessons from Chile, Mexico, and California". Cuadernos de Economía, 291-315.

SEUC (2001). Interruptible Service Contract Issues. Senate Energy, Utilities and Communications Committee. Available at https://seuc.senate.ca.gov/interruptibleservicecontractissues

da Silva, U. P. Á., da Costa, A. M., Lima, G. P. B., Lima, B. P. (2006). "*A experiência da alocação negociada de água nos vales do Jaguaribe e Banabuiú*." Available at: http://arquivos.ana.gov.br/imprensa/eventosprojetos/AlocacaoNegociadaAguaValeJaguaribe.pdf.

SNIS. (2016). *Sistema Nacional de Informações sobre Saneamento*. Available at http://www.snis.gov.br/.

SNIRH. (2018). *Sistema Nacional de Informações sobre Recursos Hídricos*. Available at: http://www.snirh.gov.br/

Wheeler, S. A., Loch, A., Crase, L., Young, M., & Grafton, R. Q. (2017). "Developing a water market readiness assessment framework". Journal of Hydrology, 552, 807-820.

Young, M. (2014). "Trading into trouble? Lessons from Australia's mistakes in water policy reform sequencing". In Water Markets for the 21st Century (pp. 203-214). Springer, Dordrecht.

Young, R. (1996). “World Bank Technical Paper n° 338 – Measuring Economic Benefits for Water Investments and Policies”.